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IN THE

Supreme Court of the United States

OCTOBER TERM, 1905.

STATE OF MISSOURI, Complainant,
vs.
STATE OF ILLINOIS AND THE SANITARY DISTRICT OF CHICAGO,
Defendants.

ORIGINAL NO. 4.

BRIEF AND ARGUMENT ON BEHALF OF DEFENDANTS.

W. H. STEAD,
Attorney General of Illinois.
H. J. HAMLIN and
JOHN G. DRENNAN,
of Counsel.

JAMES TODD,
Solicitor for Sanitary District of Chicago.

BARNARD & MILLER, PRINT, CHICAGO.

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THE STATE OF MISSOURI, Complainant, vs. THE STATE OF ILLINOIS and THE SANITARY DISTRICT OF CHICAGO, Defendants.	Original No. 4.

STATEMENT.

In this suit the State of Missouri, the complainant, files its bill in equity in this court, praying for an injunction against the defendants, the State of Illinois and the Sanitary District of Chicago, restraining the said defendants from draining into the Mississippi River the sewage and drainage of the said Sanitary District, by way of the Drainage Canal and the channels of the Desplaines and Illinois Rivers.

The complainant claims that by reason of said sewage and drainage flowing into the waters of the Mississippi, the waters of said river are polluted to such an extent as to render them unfit and unsafe to be used by the inhabitants of said State of Missouri, residing on the shores of said river or adjacent thereto, for drinking, domestic, manufacturing and agricultural purposes. An abstract of the pleadings in the case will more fully and clearly set forth and explain the alleged grievances of the complainant herein, and the defenses set up by the defendants thereto.

BILL OF COMPLAINT.

The bill of complaint alleges in substance as follows:

That complainant is a State with a population of upwards of 3,000,000 people, lying on the west bank of the Mississippi River, a navigable stream, and having a frontage on said stream of over 400 miles.

That upon the admission of Illinois and Missouri as States of the Union, the middle of the main channel of the Mississippi River was declared the western boundary of Illinois and the eastern boundary of Missouri, and that soil under the waters of said river was reserved to the States of Illinois and Missouri; and that said States have a concurrent general jurisdiction over the waters of the Mississippi River, and each of said States has exclusive territorial jurisdiction over that portion adjacent to its shown shore.

That the Illinois River empties into the Mississippi River at a point above St. Louis. That on the banks of the Mississippi below the mouth of the Illinois River are many cities and towns in the State of Missouri and many thousands of persons who use the waters of said river for their daily necessary supply of water for drinking and all other domestic, agricultural and manufacturing purposes; and that the waters of said river, in their natural condition, are indispensable to the life, health and business of many thousands of the inhabitants of the said State.

That many cities and towns below the mouth of the Illinois River, by means of waterworks, intakes, etc., use the waters of the said river as a source of water supply for the inhabitants of said cities and towns. The bill of complaint sets out, in substance, the law of 1899 creating the Sanitary District, and the provisions for the organization and operation of said Sanitary District. It also sets out the construction of the Drainage Canal, and the course of said Canal, and that it finally empties into the Mississippi River by way of the Illinois River, about forty-three miles above the City of St. Louis, Missouri.

That the work done by the Sanitary District was done as one of the governmental agencies of the State of Illinois and under sanction and authority of said State.

That the channel of the Canal is cut through the natural watershed dividing the basin of Lake Michigan from the basins of the Desplaines, Illinois and Mississippi Rivers.

That the defendants propose to drain through said channel the sewage matter of nearly the whole City of Chicago and a portion of the County of Cook, and to eventually empty said sewage into the Mississippi.

That the said sewage matter is created by a population of upwards of one and one-half millions of people, besides that created by a great number of stock yards, distilleries, etc.

That for many years past the City of Chicago has discharged its sewage matter into Lake Michigan and large quantities of it have accumulated in the bed of the Chicago River and the bed of Lake Michigan.

That the plan of the defendants, if carried out, will loosen said accumulated matter and cause it to flow finally into the Mississippi River past the homes and waterworks system of the inhabitants of the complainant.

That the amount of said undefecated sewage matter will amount daily to about 1,500 tons; and that the said matter will poison the waters of the Mississippi and render them unfit for domestic uses, and render valueless the various waterworks systems using the water of said river.

That the action of the defendants amounts to a direct and continuing nuisance and will endanger the health and lives of the inhabitants of the complainant; and the business interests of the complainant will be irreparably injured.

That the great quantities of undefecated sewage will pollute the waters of the Mississippi with germs of disease of various and many kinds. Then follow the usual formal allegations that the complainant is without remedy except in a court of equity, and the prayer for an injunction restraining the de-

fendants from doing the acts herein alleged to be a nuisance and injury to the complainant and its inhabitants.

Defendants filed a demurrer to the bill, which was argued, and the Court delivered its opinion thereon on the 28th of January, 1901, wherein the demurrer was overruled, and defendants filed their answer herein.

ANSWER OF THE STATE OF ILLINOIS.

The defendant, the State of Illinois, also filed its separate answer to the bill of complaint, in substance as follows:

That this defendant unites with its co-defendant in its general admissions, denials and allegations of new matter.

That the Sanitary District is not subject to the control of the executive department of the State of Illinois, nor are the officers of said District, in the performance of their duties as such officers. This defendant admits the appointment of commissioners to examine the Drainage Canal; admits receiving their report; and admits authorizing the trustees of the Sanitary District to turn the water and sewage of said Drainage District into the Desplaines and Illinois Rivers; and also admits that said trustees did turn said water and sewage into said rivers; that all the said acts of the Governor of Illinois were done and performed prior to the 17th day of January, 1900, when the complainant herein moved for permission to file its bill of complaint.

That the supervision of the authorities of the State of Illinois over the Drainage Canal can only be exercised by and through the lawmaking power of said State; and that the only authorities of said State authorized by law to control said Canal are the Board of Trustees of the Sanitary District of Chicago, their officers, etc.

ANSWER OF THE SANITARY DISTRICT OF CHICAGO.

The defendant, the Sanitary District of Chicago, also filed its separate answer to the bill of complaint, in substance as follows:

The defendant, the Sanitary District of Chicago, admits the character of complainant and the defendants to be as alleged in the bill of complaint; it admits the population of Missouri to be upwards of 3,000,000 people.

That the said State has a frontage on the west bank of the Mississippi River of over 400 miles; that the center of the channel of the Mississippi forms the western boundary of Illinois and the eastern boundary of Missouri; and that the soil under the waters of said river, by the Constitution of the United States, was reserved to the States of Illinois and Missouri, respectively.

It also admits that the States of Missouri and Illinois each have concurrent general jurisdiction over the waters of the Mississippi River, and that each of said States has exclusively territorial jurisdiction over that portion of said river adjacent to its own shore.

That the Illinois River empties into the Mississippi River at a point above the City of St. Louis, on the Illinois side of the Mississippi River.

That within the territory of complainant, on the banks of the Mississippi River and below the mouth of the Illinois River, are many cities and towns in said State of Missouri; that many thousands of persons rely upon the waters of the Mississippi for their daily necessary supply of water for drinking and other domestic, agricultural and manufacturing purposes; and that said waters have been so used for a great length of time.

As to whether the said waters are indispensable to the life, health and business of many thousands of the inhabitants of the complainant, and whether said inhabitants are compelled to use said waters for the purposes aforesaid, this defendant

neither admits nor denies, but leaves the complainant to make proof thereof.

This defendant denies that the use of said waters for drinking, agricultural and mechanical purposes is of value to the complainant as a State.

This defendant admits that certain cities and towns of the complainant situated below the mouth of the Illinois River do, by means of waterworks systems, etc., use the waters of the Mississippi to supply the inhabitants of said cities and towns with water for drinking and other domestic uses.

As to whether said cities and towns are compelled to use said waters for the purposes aforesaid, or whether the supply of said water is pure and wholesome, this defendant neither admits nor denies, but leaves the complainant to make proof thereof.

As to whether the said waterworks systems are constructed for the purpose of taking water from the Mississippi only, and not from any other source, this defendant neither admits nor denies.

This defendant admits the passage of the law of 1899 creating the Sanitary District; and admits complainant's allegations as to the purport of that law. This defendant admits the complainant's allegations as to the relative geographical situation of Lake Michigan and the various rivers and the Canal forming the drainage system of this defendant.

This defendant denies that the sewage of said district flows into the Chicago River and Lake Michigan.

This defendant avers that the greater portion of the sewage of said district has been for many years discharged into the Desplaines and Illinois Rivers.

This defendant admits the construction of the Drainage Canal, as alleged in the bill of complaint.

That all the acts of this defendant done in connection with said work have been in strict pursuance of authority given by the State of Illinois.

This defendant admits that it has completed the Drainage

Canal and has received into said channel the sewage matter of said District; and that it has caused said sewage to flow through said channel into the Desplaines River.

This defendant denies that said sewage will be carried into the Mississippi River by the homes of inhabitants of complainant and by the cities and towns and their waterworks systems within complainant.

This defendant admits the allegations of complainant as to the population of the Sanitary District and the nature of the business enterprises carried on within said district, except as to the distilleries.

This defendant avers that the obnoxious matters created by said establishments will be rendered innocuous before being received into the sewage system of said district.

This defendant denies that large quantities of sewage matter have accumulated upon the bed of the Chicago River and of Lake Michigan; and denies that plans, adopted by this defendant, will loosen said matter and cause it to flow into the Desplaines River.

The defendant avers that for many years a large portion of the sewage matter of said district has been pumped into the drainage channel heretofore constructed and has flowed into the Desplaines River.

That such of the sewage matter as has been discharged into the Chicago River and into Lake Michigan has been dissipated by the cross-currents of said lake and has wholly lost its noxious character; that any of such matter as might have accumulated upon the bottom of said lake has been covered by deposits of earth excavated from the foundations of said city. This defendant denies that the waters of the Mississippi will be poisoned and polluted if it shall carry out its plan and convey all the sewage of said District into the Desplaines River; and denies that it will thereby destroy the adaptability of said waters for domestic or other uses. The defendant expressly denies that the carrying out of its plans will render valueless the waterworks systems aforesaid; and that it will injure

the business of the cities and towns of complainant in furnishing water to private consumers, or that it will disable them from furnishing water for domestic or other purposes.

This defendant expressly denies that it will injure the property and business of said cities, or that it will create, as to them, a direct and continuing nuisance.

It neither admits nor denies that the aforesaid sewage will amount to 1,500 tons daily.

It denies that said sewage will be deposited in the bed of the Mississippi, and that it will pollute and poison the said waters with germs of diseases of various kinds or with any germs of disease whatever.

This defendant avers that the turning into the Desplaines River of said sewage, together with 300,000 cubic feet per minute of the pure water of Lake Michigan, will greatly improve the quality of the waters of the Mississippi.

This defendant then alleges the Act of 1822, by which the United States granted to the State of Illinois land for canal purposes, and recites the construction of what is known as the Illinois and Michigan Canal and improvements made upon said Canal, and that the City of Chicago deepened said Canal for the purpose of receiving its sewage and thereafter used the Canal for said purpose.

That since a time prior to 1865, by means of pumps situated at Bridgeport, nearly all of the sewage of the Chicago River has been discharged into said Canal and thence into the Desplaines River at Lockport.

That of the 1,500,000 people embraced within the limits of Chicago, the sewage of 200,000 of them has been discharged at other points than into the Chicago River.

That the sewage of the residue of the population has been discharged into the Chicago River and has been carried by the aforesaid pumps into the said Canal, except upon occasions of flood or other unusual occurrences, when the current of the river was sent into the lake.

That in 1881 larger pumps were used at Bridgeport and

said pumps have been continually working away the said sewage through the said Canal into the Desplaines River.

That the work of deepening the said Canal for the purposes aforesaid necessitated an expenditure of about One Million, Nine Hundred Fifty-five Thousand, Three Hundred Forty Dollars ($1,955,340), besides a very great sum of money in the erection and operation of the pumps at Bridgeport; that all of this work was open and notorious and in the sight of all men.

The answer then recites the formation of the Sanitary District and describes the magnitude of the work accomplished by said District and its great publicity.

That all the acts of defendant are open, notorious and are largely matters of record open to all citizens; that there are a number of lines of railways passing between Chicago and St. Louis within plain sight of the work as it progressed, said railroads being traversed by hundreds of thousands of citizens, day and night.

That the work of the Sanitary District became known in all the cities of the United States; that in the prosecution of its work it has occupied more than 4,000 acres of land in Cook County; more than 500 acres in DuPage County; nearly three thousand acres in Will County, at a total cost of more than three millions of dollars.

That during the nine years since the institution of the work upon this enterprise this defendant has spent upon said work more than thirty-three million dollars.

That this defendant had completed its channel prior to the filing of the bill of complaint herein.

That on the 2d of January, 1900, the water was turned into said channel, filling the said channel for a distance of twenty-eight miles to an average depth of twenty-two feet with prisms of water varying from 110 feet to 200 feet in width at the bottom and from 160 to 290 feet at the water line.

That the work was completed by the lowering of the bear trap dam on the 17th day of January, 1900, at 11:16 o'clock A. M., prior to the time complainant presented its motion to

this Court for leave to file its bill of complaint and five days prior to the time that said bill was filed.

That the complainant had notice of the great work accomplished and great expenditures of public money raised by taxation and sale of bonds, which are liens upon the tax funds to be hereafter levied.

That having said notice and having so waited as aforesaid, complainant has been guilty of laches and is estopped to further urge its cause.

The answer then describes the size and capacity of the Canal and alleges that its capacity is sufficient to furnish pure water from Lake Michigan at the ratio of twenty cubic feet to one cubic foot of liquid sewage.

This defendant then sets forth the legislative acts conferring upon it the authority to accomplish aforesaid work, and the acceptance by the State of Illinois of the completed work as presented to the commissioners appointed by the Governor to inspect and report upon said work.

This defendant avers that the distance by way of the Drainage Canal and the Illinois River from Robey Street, Chicago, to the mouth of the Illinois River is 322 miles.

That the Desplaines, Kankakee and Fox Rivers unite to form the Illinois River and are the natural drainage systems for an area of country occupied by not less than a million and a half of people outside of said Sanitary District, embracing an area of twenty-five thousand square miles.

The answer then enumerates a number of cities draining into the said rivers, giving the population and the nature and extent of the manufacturing industries of said cities, and alleges that the sewage from all these cities has for a great length of time flowed by way of said rivers into the Mississippi.

That in addition to the sewage carried into the Mississippi by the Illinois River is the sewage of the vast territory tributary to the Mississippi River and its tributary streams.

That said territory embraces a large portion of a number of the States of the Union, and that the population of said territory is in the neighborhood of fifteen million people.

The answer then names many of the large cities and towns, the sewage of which drains into the Mississippi and its tributary streams, and gives the distance of said towns from the mouth of the Illinois River; and alleges that in many of said cities industries, such as cattle yards, slaughter houses and rendering establishments, are conducted.

That the Mississippi River and its tributaries form the natural drainage system of a vast region of country; and that the additional amount of sewage discharged through the channel of this defendant is trifling in amount as compared with the enormous volume of sewage received into said Mississippi River above the cities and towns of complainant mentioned in this bill.

That by natural laws governing running water in large bodies the said sewage is deprived of all its deleterious qualities by processes of vaporization, attrition and chemical conversion, etc., so that in the end the water purifies itself.

That in addition to the foregoing, this defendant is removing from the sewage all solid material and is diluting all of the liquid material by an addition thereto of twenty cubic feet of Lake Michigan water to every cubic foot of sewage.

SUPPLEMENTAL BILL OF COMPLAINT.

The complainant alleges that since the filing of the original bill on the 17th day of January, 1900, the defendants have opened and put in operation the Drainage Canal, and that the said sewage permitted to flow through the same has polluted the water of the Mississippi and has destroyed the value of the same for primary purposes and for drinking and domestic purposes, and has caused and is causing much sickness to persons living along the banks of said river in the State of Missouri, and will continue to do so unless said acts of the defendant are restrained.

That under the law authorizing the construction of said channel it was required that said sewage be diluted with not

less than 20,000 cubic feet of water per minute for each 100,000 inhabitants of said Sanitary District; and that the defendant, the Sanitary District, has not at any time, since the opening of said channel, furnished such an amount of water dilution.

That since April 20, 1901, the said defendant, acting under orders of the Secretary of War, has reduced such dilution to not exceeding 200,000 cubic feet of water per minute in the aggregate, or about 10,000 cubic feet for each 100,000 inhabitants of said district, and proposes hereafter to limit the maximum dilution to that amount.

The defendants filed a joint demurrer to the fourth paragraph of the supplemental bill, which demurrer was sustained.

ANSWER OF THE DEFENDANTS TO THAT PART OF THE SUPPLEMENTAL BILL NOT DEMURRED TO.

It is denied that on the 17th day of January, 1900, the complainant filed its original bill, but on that day moved the Court for leave to file its said bill, and that said bill was not filed until five days thereafter.

Defendants admit that on the 17th of January, 1900, five days before the original bill was filed, the Sanitary District did open said channel and did permit the sewage of said District to flow therein.

The defendants deny that said sewage has polluted the waters of the Mississippi and deny that said sewage has destroyed the value of the waters for primary uses and for agricultural, manufacturing, drinking and domestic purposes.

The defendants deny that said sewage has heretofore, or will hereafter, cause sickness to persons living along the banks of the Mississippi in the State of Missouri.

Defendants aver that they will prove, if permitted, that the turning into the Desplaines River of said sewage, together with the pure waters of Lake Michigan which accompany the same, has not polluted or in any way impaired the value of the waters of the Mississippi for the aforesaid purposes.

Defendants aver that the large volume of pure water which accompanies said sewage has improved the quality of the waters of the Illinois and Mississippi Rivers, and has greatly improved the conditions which existed prior to the time when said sewage and waters were turned into said river.

Defendants further say that the City of St. Louis, situated about forty miles below the mouth of the Illinois River, having a population of 575,238 inhabitants, by the census of 1900, and suburban towns and villages having a population of 50,000 in addition thereto, discharge their sewage into the Mississippi opposite said city.

That said sewage, coming directly and undefecated from the sewers of said cities, towns and villages, causes a much greater pollution of the waters of said river from said city to the southern boundary of said State than can possibly be produced by the waters coming from the said Illinois River.

That the waters of the Illinois River flow in their natural course for about 358 miles after receiving the sewage from the Sanitary District.

That said waters so flowing for said distance have been relieved of their noxious character by the natural law relating to running waters in large bodies.

That if the waters of the Mississippi below St. Louis have been polluted and become injurious to the inhabitants of said State, such pollution cannot be imputed to defendants, but on the contrary must be imputed to the City of St. Louis, a municipality of complainant.

That the aggregate population of said city and its suburbs is 625,000, or about one-half of the population of the Drainage District of the Sanitary District of Chicago.

That the intake of the waterworks system of the City of St. Louis is located on the west bank of the Mississippi, only about three miles below the mouth of the Missouri River, which river is nearly as large as the Mississippi at the point of confluence; that the waters of the Missouri flow in an easterly direction and bear directly across the Mississippi toward the

Illinois shore, pressing upon that shore the water from the Mississippi and Illinois Rivers.

That by this natural flow of the waters of the said rivers, the waters of the Illinois are pressed upon the east bank of the Mississippi River and do not mix with the waters flowing along the west bank of said Mississippi until said waters have passed the intake of the water supply of St. Louis.

That the waters received at the intake of the water supply of St. Louis flow wholly from the Missouri River.

That if said waters so furnishing the water supply of said city are polluted, to any extent whatever, such pollution is caused by the sewage and filth from the cities and towns on the banks of the Missouri River above its mouth, many of which towns and cities are situated within the complainant.

That the Mississippi River, at the mouth of the Illinois River, is a much larger stream than is the Illinois River.

That the flow of water from said Mississippi at that point exceeds the flow of the Illinois River under normal conditions about six times in quantity ever since the increased flow from the waters of Lake Michigan.

That in consequence of this fact, the waters flowing from the said Illinois River are pressed upon the Illinois shore until said waters have passed the mouth of the Missouri River.

That at no point in the Mississippi River below the mouth of the Illinois River and above the City of St. Louis do the waters of the Illinois River reach a line west of the center of the Mississippi.

PART ONE.

I.

DESCRIPTIVE AND HISTORICAL FACTS.

The City of Chicago.

The City of Chicago has a population, according to the census of 1900, of 1,698,575, and an estimated population in 1903 of 1,878,000.

The water supply for the City of Chicago is derived from Lake Michigan by means of intakes situated in the lake, drawing the water by means of pumps, through connecting tunnels, into the water supply of the city. Since the city was established its water supply has been derived from Lake Michigan.

Prior to 1900 the sewers of the City of Chicago emptied either into Lake Michigan or into the Chicago River, which, in turn, emptied into Lake Michigan. The emptying of the sewage of the City of Chicago, as the city grew, affected its water supply, and it was necessary, on account of the public health of the city, to take steps looking to the elimination of the sewage of the city from Lake Michigan. When Chicago was a young city the surface was so slightly above the level of the lake that it was impossible to put in sewers. The drainage was all in open ditches. In order to establish a sewage system, it required the elevation of the streets. The elevation of the streets admitted of the putting in of sewers which would have power enough to press a flow towards the outlet. The slope is very slight indeed. In many instances it is as small as half an inch to 100 feet, and in some places less than that.

The result of this was that there was eventually an accumulation of organic matter in the sewers, which was flushed out at times of heavy rainfalls or melting snows. This flushing out was at times done mechanically. Very large square tanks, mounted on trucks that took from four to six horses to haul

them around, would be stopped over a manhole, a spout let down, the valve opened and the water emptied from the tank into the sewer, flushing it out in that way. (6613.)*

The Sanitary and Ship Canal.

The Sanitary and Ship Canal has been the outcome of Chicago's necessities. The conditions affecting Chicago's drinking water had gotten steadily worse from the days when it began to be a city. The conditions were such that the public generally was excited and the public men of the city determined to see what could be done to relieve the city.

It reached a period in 1886 that the City Council authorized the Mayor to appoint an expert commission to decide what should be done for the city. That commission was appointed in January, 1886, and Rudolph Hering was made the engineer in charge. His associates were Benezette Williams and Samuel J. Artingstall. These gentlemen were authorized to employ expert help, to make surveys and investigations and to prepare a report accompanied by their recommendations.

The preliminary report was handed in in January, 1887. (6980.)

In 1889 the Sanitary District Law was passed, authorizing the creation of sanitary districts in the State of Illinois.

Under that law a Board of Trustees was elected, consisting of nine trustees, with power to organize, decide upon plans, levy taxes, enter into contracts and prosecute the work of the building of the Drainage Canal, as they should deem best. This Board adopted a project for a waterway from Chicago to Lockport, this waterway to cause a flow of the waters of Lake Michigan through the Chicago River and through the channel which they constructed artificially, and discharged into the Desplaines River at or near Lockport, Will County, Illinois. (6616-17.)

The Sanitary and Ship Canal follows the general location of the old Illinois and Michigan Canal from Chicago to Lock-

* Reference is made only to pages of Printed Record.

port; it traverses the territory which is partly tributary to Lake Michigan and partly to the Illinois watersheds. It connects with the west fork of the south branch of the Chicago River at Robey Street in the City of Chicago; runs in a southwesterly direction through a clay formation and crosses the divide near the "Summit Range line". The lowest point in the divide between the watershed of the Illinois, the Desplaines Valley and that of Lake Michigan is almost on this summit range line. Before the building of the "Ogden Ditch" the natural surface at its lowest point was 11.72 feet above Chicago datum. Chicago datum is a plane of reference adopted for horizontal elevations by the engineers of the Illinois and Michigan Canal when its construction was entered upon. It so happened that this elevation corresponded with the low water of 1847, and hence Chicago datum is always spoken of as the low water of 1847.

The first seven or eight miles of this channel is through a clay formation which can be readily dredged, and the cross-section of this stretch of the channel is now less than what it is to be ultimately. It is only 110 feet wide on the bottom, the side slopes being 1 foot vertical to 2 feet horizontal, giving a surface width with a minimum depth of water 22 feet of 198 feet. At the end of this stretch of channel material was encountered which could not be readily dredged. It is described as glacial drift. There the full sized channel was entered upon. This full size channel is 202 feet wide on the bottom, with side slopes as before of 2 feet horizontal to 1 vertical, and the resulting width at the water line is 290 feet, with a minimum depth of water 22 feet.

This cross-section of the channel is held for 5.3 miles until Willow Springs is reached; there the rock was encountered. The territory from there on to Lockport is either wholly rock or is underlaid by rock.

The channel contracts at this point to 160 feet in width. The grade is increased from 1 foot in 40,000 feet, which is equivalent to an inch and five-eighths to the mile, to 1 in 20,000 feet.

The length of this cross-section is 14.95 miles. Seven miles of this distance is through cut in rock, the sides are cut practically vertical with two off-sets of 6 inches each on each side, so that the surface width is 162 feet. Wherever the rock did not come to the surface walls were built from the rock at the elevation found to a height of 5 feet above Chicago datum.

It was necessary that perfect control of the flow through this channel should be maintained; and to accomplish this controlling works were erected at Lockport. These works consisted of seven lifting gates of the Stoney type, and one bear-trap dam. The gates have an opening of 32 feet each. They are counterbalanced and operated by winches, so constructed that two men can raise or lower the gates under pressure, although each gate weighs 62,000 pounds.

The bear-trap dam was adopted because it was desirable to have a movable dam which could be raised or lowered to admit of the passage of ice or drift from the channel. The original bear-trap dam dates back to 1836 and was invented by Hazard and White. The one which we are now discussing is the largest ever attempted. It has 160 feet clear waterway, with possible oscillation of 17 feet. The dam itself is essentially two immense leaves of steel—the down stream leaf hinged at its lower side to massive masonry, the up stream leaf hinged to the down stream leaf like the backs to a book. The up stream leaf plays free upon a masonry barrier or a dam, and is supported at intervals of 2 feet upon wheels which travel on tracks bedded in this masonry dam. The dams fit in between the masonry bulkheads with only sufficient play between them to keep from binding. The space beneath the dams forms a water chamber which is supplied by a tunnel running the full length of the dam. Water is admitted to this channel through valves operated by hand power. There is a discharge conduit beneath the dam to operate the dam. The process is as follows:

If it is to be raised, the valve controlling the discharge of water from beneath the dam is closed and the intake valve is opened. The water rushes into the chamber below the leaves

and forces the leaves up. This is done until the proper height is reached, when the discharge valve is opened and the intake valve adjusted so that there should be a steady flow through the tube. The volume of water is kept constant under the dam. To lower the dam the intake valve is closed and the outlet valve is opened. The water flows out of this chamber beneath the dam and it settles down. The whole mechanism can be operated by one man. It operates so perfectly that the Stoney gates are rarely used. The entire flow can be shut off in five minutes and in as many more minutes a flow of 400,000 cubic feet per minute can be discharged over the dam. There are thirteen bridges across the Drainage Canal. Seven of these are highway bridges and six are railroad bridges. They are all of a movable type. The sanitary law compels this style of construction, as it is to be a navigable channel.

Work was begun on the Sanitary Canal on the 3d of September, 1892. The water was let into the channel on the 2d day of January, 1900.

The inspection of the State Commission had extended over nine months prior to this date, and on the 17th day of January the commission was assembled and the president of the commission, in the name of the State of Illinois, authorized the Board of Trustees of the Sanitary District to lower the bear-trap dam and cause the water to flow to the westward.

This lowering of the bear-trap dam was on January 17, 1900, at 11:05 A. M. (6616 to 6620.)

The Illinois and Michigan Canal.

Prior to the opening of the Drainage Canal, on the 17th day of January, 1900, the bulk of the sewage of Chicago was disposed of by pumps through the Illinois and Michigan Canal, located at Bridgeport.

The Illinois and Michigan Canal was commenced about the year 1836 and completed in 1848. It extends from a junction of the south fork of the south branch of the Chicago River in

the City of Chicago and in a southwesterly direction across the divide between the Lake Michigan watershed and the Illinois Valley watersheds, through to Peru, Illinois, a distance of about 96 miles. This Canal had a navigable depth of about 5 feet and a navigable width of about 60 feet. Its locks were 110 feet long and 18 feet wide. What is known as the summit level extends from the south fork of the south branch of the Chicago River through to Lockport, a distance of about 29 miles. The summit level since 1884 has been supplied by pumping works located at Bridgeport, in the City of Chicago. The pumps were under a guaranteed capacity of 60,000 cubic feet per minute. Prior to the erection of the pumps at Bridgeport the summit level was supplied by water coming in through what is known as the Sag Valley. There was a dam at Blue Island, draining off the Calumet River and dividing its flow, a portion of it through a shallow channel, dug for the purpose, and conveying it into the Illinois and Lake Michigan Canal at Sag Bridge. At a period prior to 1870 this supply became inadequate and pumps constructed on the principle of the stern wheel to a stern wheel steamboat were put in at Bridgeport for the purpose of supplying water for this summit level.

At some time prior to 1870 the City of Chicago undertook to deepen the summit level and get a gravity flow from the lake through the canal. This work was in progress at the time of the Chicago fire, and a very large sum of money had been expended by the city, approximating a million dollars or a little more, and after the Chicago fire the State of Illinois refunded this expenditure to the city. This gravity flow proved inadequate because the channel had not been made deep enough, and pumping works were again established at Bridgeport; and the pumps that were put in had a guaranteed capacity of 60,000 cubic feet per minute and lift between 4 and 5 feet. These pumps did not, in practice, accomplish what they were claimed to do, and the flow fell to in the neighborhood of 50,000 cubic feet. It ranged between 45,000 and 50,000 cubic feet a minute. This supplied the summit level from Bridgeport to Lockport

and the intermediate level between Lockport and the upper pool at Joliet. At Joliet the canal and the Desplaines River flowed together through the upper pool as far as Dam No. 1. At Dam No. 1 there was a lock called "Lock No. 5." It passed the flow from the upper pool to the middle pool. The middle pool was created by the building of Dam No. 2 at Jefferson Street, in the City of Joliet. At Dam No. 2 the river and the canal again separated and the canal had an independent course from that point through to La Salle, where it emptied into the Illinois River. The supply of what is known as the Chanahan, or 12-mile level, extending from Joliet to Chanahan, was taken from the Desplaines River at its junction with the waters coming through the canal from the Bridgeport pumping works. At some seasons of the year the supply of water from the Desplaines was very small indeed, and the canal was almost wholly dependent for its availability as a navigable stream upon the water pumped from Bridgeport.

These pumps were completed in 1884 under a contract with the City of Chicago, and paid for by the City of Chicago.

The forebay from which this water was pumped connected directly with the south fork of the south branch or what was known as the Stock Yards Branch. The water entering the pumps came partly from the Stock Yards Branch and partly through the south branch of the Chicago River from Lake Michigan. There was a certain small flow of water due to sewage discharged into the Stock Yards Branch, which met the flow from the lake, and the two mingled and were drawn into the pumps.

The water flowing through the summit levels at a very slow velocity, probably a mile an hour, was a black liquid with a very foul odor, and would leave a greasy black stain on anything that was put into it. The water in the two pools at Joliet was at some seasons of the year as bad as that in the canal proper, because there was so little dilution coming in from the Desplaines River; and it was only bettered by what water came in from the Desplaines River. At some seasons of the year that

flow was large and the conditions were very much improved, but in the dry seasons there were foul, horrible pools. (6613-14-15.)

The Discharges of the Illinois and Michigan Canal.

The canal was deepened, between 1865 and 1871, and the flow was only about 9,000 cubic feet per minute. It was sufficient for the sewage and the pumps were put in the latter part of 1884. The operation was commenced about the end of the year 1884. From 1884 to 1900 the average volume of sewage pumped from the Chicago River into the Illinois and Michigan Canal was approximately 50,000 cubic feet per minute. (6652.)

In 1900 the highest record of the Illinois and Michigan Canal was on February 8th—57,677 cubic feet per minute. The lowest, when there was anything doing at all, was 14,800 cubic feet. The average was 26,768 cubic feet per minute. The canal appears to have been shut down entirely from the 1st of January, 1901, to the 24th of April, 1901. The minimum was on April 24th, 3,840 cubic feet. On July 3, 1901, the maximum was 29,206 cubic feet, and the average for the twenty-six weeks was 20,073.

In 1902 the pumps were started May 1st. The minimum was 9,200 cubic feet per minute; the maximum, 25,080. The pumps were only run for twenty-seven weeks and the average was 22,488.

The first six months of 1903, on January 13th, was the minimum, 1,913. On June 5th was the maximum, 28,114; the average for the twenty-six weeks, 21,996. (6631.)

After this sewage was pumped into the Illinois and Michigan Canal it flowed through that canal to Lockport, where a portion of it was discharged into the Desplaines River, over a waste weir, or else passed through the wheels of the water power at that point. What did not enter the river at this point entered it after the Desplaines River reached what is known as the upper basin at Joliet. The complete mingling was in the basin at Joliet. (6653.)

The Improvement of the Chicago River.

The work of executing the plans of the District had gone steadily on. Chicago River, as it was in 1898, did not afford an adequate channel to supply the water which the Sanitary District Law required to flow through the channel.

Prior to the beginning of the work by the Sanitary District, the flow through the Chicago River would have been limited to 150,000 cubic feet, and the plans of the Sanitary District provided for a widening of the Chicago River uniformly for 200 feet, deepening it for the central 100 feet to 26 feet below the water surface, making the depth at the dock lines 16 feet. This would give the river a capacity of 480,000 cubic feet per minute and a velocity not exceeding a mile and a quarter per hour.

The district is also engaged in removing center pier bridges from the river and substituting therefor bascule bridges. Seven bascule bridges have been completed. The plan contemplates the construction of twenty-two bridges over the Chicago River. (6621.)

The Improvement of the Desplaines River.

The channel of the Desplaines River south of Lockport was entirely inadequate to the demands which would be made upon it by the combined flow of the waters of the Desplaines and the discharge from the Sanitary and Ship Canal. It was therefore necessary that the District should deepen and enlarge this channel, which it has done to an extent which enables it to carry these combined waters safely through the City of Joliet.

The District has made provision for the flow of 1,500,000 cubic feet of water per minute. For one mile south of the controlling works an entirely new channel was made for the Desplaines River. That brought it to the precipitate slope of the valley. There, instead of making a new channel, the District bought lands on each side which would be submerged. This method of caring for the water was adopted as far as the E. J. & E. bridge just north of Joliet. From that point into the upper basin the District made an entirely new channel for the

Desplaines. In the upper basin, the width of which was 300 feet, the basin was deepened to give a sufficient cross-section to carry 1,500,000 cubic feet of water per minute. The Sanitary District was compelled by the Illinois and Michigan Canal Commissioners to rebuild Dam No. 1, which it did. The middle basin was destroyed, tearing out Dam No. 2 and maintaining navigation in the Illinois and Michigan Canal by building a channel for said canal from Dam No. 1 to the guard lock located at Jefferson Street. After tearing out Dam No. 2, which made the second pool, the river was widened and deepened between Jackson Street and Jefferson Street. This widening and deepening from Jefferson Street was continued through to a point about 800 feet south of the Rock Island bridge. From that point to the mouth of Hickory Creek a massive embankment was built to prevent the overflow of the adjacent territory by the flood waters. The District was compelled by the City of Joliet to build new bridges at Cass Street and at Jefferson Street. (6622.)

Grade of the Channel.

The grade of the channel falls 5.62 feet, and with the minimum depth the water surface is supposed to be parallel to that grade, so that when there is only 22 feet of water in the channel, which may happen sometimes, the fall of the water surface should correspond with the water in the channel, 5.62 feet. (6623.)

Length of the Drainage Canal.

The length of the canal from Robey Street, Chicago, to Lockport is 28.05 miles. From Robey Street to the mouth of the Chicago River is 6 miles. The theory upon which was based the work of the canal is that there would be a fall of 2½ feet. That has not been sustained. The fall is about 2 feet now and that is being diminished as the cross-sections of the river are increased. (6623.)

Cost of the Drainage Canal.

The construction cost, up to the first of January, 1904, has been	$27,179,781.45
The completion account and maintenance account.	548,988.94
Administration account in all its departments, engineering, clerical, law, treasury, police and general account.	3,828,615.45
Right of way—this covers also the buildings which had to be destroyed, etc.	4,808,338.17
Interest on bonds.	5,395,033.70
Interest on tax warrants	468,453.69
Taxes.	24,062.45
Sundry accounts.	249,894.95
Making a total of	$42,503,168.80

(6623-6624.)

Sanitary District of Chicago.

The original Sanitary District took in all of the City of Chicago north of Eighty-seventh Street except a part of Rogers Park and Norwood Park and 42 square miles of the country lying directly west of that portion of the city, embracing in all 185 square miles. This district was laid out under authority of the law passed in 1889. Under the acts of the Legislature since 1889, extending the boundary of the Sanitary District, 78.6 square miles of territory was annexed on the north side known as the North Shore District, and on the south side 94.48 square miles was annexed, known as the Calumet District. That completes the taking into the Sanitary District of all the City of Chicago. The whole city is now in the Sanitary District.

It is proposed to reverse the flow of the Calumet River by constructing a channel from a connection with the Calumet River near Blue Island. This channel extends southwesterly through what is known as Sag Valley to a junction with the Sanitary and Ship Canal at or near Sag Station on the Alton Railroad. This channel will reverse the flow of the Calumet River and prevent the discharge of its waters into Lake Michigan at all times except in excessive floods. Provision can be

made for taking the entire flood waters of the Calumet region through the channel.

On the north it is proposed to extend the north branch of the Chicago River northward as far as Evanston and make a connection with Lake Michigan at that point, at a point almost on the boundary line between Evanston and Winnetka. The lake level being the same at this point of junction as it is at the mouth of the Chicago River, it will be impossible to get a gravity flow through this channel; and therefore pumping works will be erected at the north end, designed to pump 60,000 cubic feet of water per minute into this new channel. Into this channel all the sewage arising along the north shore is to be delivered by sewers constructed for that purpose. (6624-5-7.)

The Population of the Sanitary District of Chicago.

The population of the City of Chicago by the census of 1900 was 1,698,575. Making up the population curve, based upon past experiences and future probability, brings that population down to 1903 as 1,878,000 at the end of the year. The population of the Sanitary District is 1,942,000. (6627-6628.)

Plans for Diverting Sewage from Lake Michigan.

The general plans of the District for providing a means of carrying off the sewage have been described. The city, in connection with the Sanitary District, is at work with a system of intercepting sewers both from the north and the south sides. The city has built a conduit in Thirty-ninth Street, 20 feet in diameter and having a capacity of 120,000 cubic feet of water per minute. At the lake end of this conduit a pumping station has been established in which there are to be six pumps. Four of these are put in by the city for pumping sewage from the intercepting sewers, sewage mingled with lake water. The combined capacity of the four pumps is 40,000 cubic feet per minute. The Sanitary District puts in two pumps which take their supply direct from the lake, without sewage pollution.

and each of these pumps has a capacity of 40,000 cubic feet per minute. They are the largest pumps ever attempted in the world. On the north side of the city, on Lawrence Avenue, the city is building a conduit to receive the intercepted sewers. That extends from the lake across to the north branch of the Chicago River. The intercepting sewers bring in the sewage from the north and south into these conduits. The pumping station is to be erected at the cost of the city and to be operated by the Sanitary District. This pumping station will have a capacity of 35,000 cubic feet of water per minute, with arrangements made for doubling that volume if it is found necessary; but the pumps will only be put in at present for 35,000 cubic feet per minute. When these improvements are completed the maximum capacity of the Drainage Canal will be about 825,000 cubic feet per minute. (6628.)

The Water Intakes of the City of Chicago.

Starting from the south, the first intake is located about opposite Sixty-first Street, and is about two miles from shore. The next one is pretty nearly opposite Taylor Street and four miles out in the lake. The next one is opposite Chicago Avenue. There are two there, one two miles out and the other four miles out. Then we come up to Lake View, and the intake is about two miles out in the lake and about opposite Mount Rose Street. Those are the sources of supply from the lake, and out at Washington Heights there are deep wells from which the water is pumped to supply that village and Morgan Park. (6628.)

The Average Flow of the Drainage Canal.

For forty-nine weeks in 1900 the average flow of the Sanitary District Canal was 188,136 cubic feet per minute. The smallest flow was on the 17th of September, 1900, 1,863 cubic feet per minute, and the largest was on the 26th day of the same month, 326,791. During 1900 the dam at Lockport was entirely closed for a few hours. This was done on two or three

occasions when vessels got stuck in the channel, and it was shut off long enough to relieve them. Water has flowed through to the lake but once since the channel was opened. Once there was a freshet in the north branch—it was a general freshet and it was not watched close enough to take care of it—and that flow began to go towards the lake, and as soon as that was noticed it was checked in a very short time. This did not extend to exceeding two hours.

On March 16, 1901, was the largest flow of the year, being 406,227 cubic feet per minute. On October 3, 1901, was the lowest, 139,427 cubic feet. The average for the year was 242,323 cubic feet. In 1902 the largest was on December 26th, 339,610 cubic feet. The average for the year was 257,006 cubic feet. For the first six months of 1903 the greatest flow was on June 5th, 401,425 cubic feet per minute. The lowest was May 30th, 248,063 cubic feet. The average was 312,692 cubic feet. (6629-6630.)

The Desplaines River.

The Desplaines River is one of fluctuating volume. In certain seasons of the year it is almost dry. In other seasons of the year it is a stream carrying very large volumes of water, the maximum volume of which being as high as 800,000 cubic feet per minute. The fall of the stream for a distance of about 27 miles southwest from Chicago is slight. When it reaches Romeo the valley drops off rapidly and the stream, which follows the trough of the valley, flows very rapidly.

From the controlling works at Lockport to the upper basin at Joliet it has a fall of about 30 feet, and at Lockport it enters the basin formed by Dam No. 1. Passing over that dam, it enters a large channel made by the Sanitary District and falls quite rapidly to Lake Joliet. Since the diversion of the Desplaines River, made by the Sanitary District in 1893, there is no town draining into the Desplaines between Lyons and Lockport. The Sanitary District Canal lies between the towns in the valley and the Desplaines River. Riverside drains into it. Grossdale drains into it, through Salt Creek. The population

of Riverside is about 1,600. Then the next town draining into it is Maywood on the west, and River Forest on the east. Then the next town of any consequence is Desplaines. At Joliet there is a rapid fall in the channel from Dam No. 1 to the head of Lake Joliet, which is about 3½ miles southwesterly of Dam No. 1. The fall in that distance is approximately 21 feet. Lake Joliet is a widening of the stream and is probably a half mile wide and something like five miles long. There is a very slight fall from the head of Lake Joliet, which is practically Brandon's Road through to the head of Treat's Island.

For the distance of about a mile from Treat's Island there is a fall of nearly 10 feet. From there the fall is gradual until you reach the pool made by the Marseilles dam. The water is backed up by the Marseilles dam to somewhere in the neighborhood of 20 miles. (6650-51.)

The Illinois River.

From the point where the Drainage Canal empties into the Desplaines River at Lockport, the fall is quite rapid to a point somewhere below Morris. The lower portion of the Illinois River, especially that part of the Illinois River from La Salle to the mouth of the Illinois at Grafton, is very sluggish and consists of a series of pools in which the current is very slow, and in which opportunities for sedimentation abound. In the lower reaches of the river the current is so slight as to be hardly noticeable. At intervals, in the course of the river, dams are located; one at Marseilles, between Morris and Ottawa, where the water is backed up a distance of 20 miles; one at Henry, 540 feet long and 6½ feet high, that backs the water up 29 miles, the length of that pool being 29 miles; one at Copperas Creek, 59 miles from Henry and below Peoria, the back water from Copperas Creek being felt as far back as Henry. The next dam after passing Copperas Creek is at La Grange. Its pool is 58 miles long. The back water extends back to Copperas Creek. The height of the dam at La Grange is 7.33 feet and its width

is 818½ feet. The length of the Copperas Creek dam is 640 feet.

From La Grange to Kampsville is 48 miles, and that is the last of the dams in the Illinois River. The La Grange and Kampsville dams were built by the United States Government. The width of the Kampsville dam is 1,200 feet and its height 7.3 feet. From Kampsville it is 31 miles to the Mississippi River. These dams accentuate the tendency of the river to form pools and back waters. At Joliet and above Peoria there are wide expansions of the river known respectively as Lake Joliet and Lake Peoria. In these expanded reaches the current is very slight and the body of water as a whole is almost entirely quiescent. At many points along the course of the river, especially below La Salle, the banks of the river are low and an increase in the height of water in the river causes an overflow of the surrounding country, flooding the meadows and lowlands adjacent to the river bank. In the lower 225 miles of the Illinois River there is a fall of only about 30 feet, and the extremely sluggish current thus produced affords nearly ideal conditions for sedimentation. During the flood stages the valley of the Illinois River becomes virtually a great lake, into which flood waters from the upper portions of the valley and tributaries are precipitated, and from the lower end of which they pass out in diminished and equalized volume. (6163 and 6651.)

The Pollution of the Illinois River Exclusive of the Sanitary District.

The sewage of Joliet, a city with a population of some 29,000, empties into the Desplaines River, as does also the sewage from a number of the suburban towns near Chicago.

On the Illinois River the sewage from Ottawa, a sewered town with a population of about 11,000, and the sewage of La Salle and Peru, with a combined population of nearly 20,000, also empties into the Illinois River. At Pekin, a sewered town, with a population of about 9,000, considerable sewage and distillery refuse also enters the river. The sewers of Havana also

discharge into the Illinois River. Beardstown, with a population of about 5,000, is the last town upon the Illinois River contributing a very large amount of sewage, the other towns below Beardstown being relatively small communities. A very large amount of pollution enters the Illinois River at Peoria, with a population of about 56,000. In addition to the sewage of the town, the drainage from the stock yards and the distilleries enters the river here. The number of cattle fed at Peoria during the last ten years has varied from 40,000 head of cattle to 18,000, as fed in 1903. These cattle are fed on the waste material from the distilleries after the alcohol has been distilled which is called "distillery slop." The amount of manure from these cattle sheds, when they were feeding 40,000 head of cattle, which manure is thrown into the Illinois River, amounts to the enormous aggregate of 2,400,000 tons; and when 18,000 head of cattle were being fed at the towns of Pekin and Peoria in 1903, it amounted to the enormous aggregate of 1,080,000 tons. All the excreta from the cattle fed at Peoria and at Pekin is run into the Illinois River. It is not an unfrequent occurrence in times of a gradual rise in the river at Peoria for islands of manure to be floated off down the river, and on one occasion the island was so large as to be unable to pass through the Pekin bridge.

The Pollution from the Tributaries of the Illinois River.

The Kankakee River, which unites with the Desplaines to form the Illinois above Morris, also receives sewage from Kankakee, a city of a population of about 14,000, and other communities. The Fox River, which enters the Illinois above Ottawa, receives the sewage from Aurora, with a population of some 25,000, and of Elgin, with a population of about 23,000. The Big Vermillion River, entering the Illinois River above La Salle, also receives sewage from Streator and Pontiac, with a combined population of about 19,000. The Sangamon River, one of the chief tributaries of the Illinois, receives a consider-

able amount of sewage from Springfield, with a population of about 25,000, and from Decatur, with a population of about 20,000, and from Bloomington, with a population of about 24,000. All along the course of the Desplaines and the Illinois Rivers, and their tributaries, in addition to these urban communities, there is a very considerable rural population often draining directly into the river or small tributary streams, and this constitutes a source of pollution and possibly infection not to be ignored. (6164.)

Population residing on the watershed of the tributaries of the Illinois River, according to the census of 1900, 1,511,387, which embraces the watersheds of the Desplaines, Du Page, Kankakee, Fox, Vermillion, Mackinaw, Spoon, Sangamon, Crooked, McKee, Macoupin and Illinois Rivers, exclusive of the Sanitary District of Chicago. (6646.)

Population of the Illinois River, including Chicago, is 2,298,326. Subtracting the Illinois River from that gives 1,698,575 for the Sanitary District. (6655.)

The average rainfall for the whole watershed of the Illinois River for ten years was 34.36 inches. (6853.)

These rains come at intervals and frequently raise the river to extreme height, and especially in the spring, when the snow is going off the ground and the ground is frozen, the decaying vegetables and other organic matter, especially from the pastures, barnyards, etc., is washed off into the smaller streams, and then finds its way into the Illinois River, producing a pollution of the stream, making it muddy and dirty during flood periods. 6854.)

The Discharge of the Illinois River at Grafton.

The average discharge from the Illinois River into the Mississippi for the ten years. 1890 to 1899, inclusive, for the low quarter, 1,904 cubic feet; the ordinary, 6,747; and the high, 36,045 cubic feet, without Chicago's contribution.

For the years 1900 to 1903, inclusive, the Chicago Drainage

Canal and the Illinois and Michigan Canal jointly have contributed to the flow of the Desplaines and the Illinois Rivers at the low period 3,801 cubic feet, the ordinary and high periods 4,162 cubic feet per second. The average discharge of the Illinois and its tributaries during the four years 1900 to 1903, inclusive, has been considerably in excess of the average discharge for the previous ten years, not taking into account the Chicago River contribution.

Comparing the discharge of the Illinois into the Mississippi, the low flow for the latter four years, as compared with the former ten years, was nearly three times as great, the ordinary flow at the high or flood flows about 80 per cent. more, these exclusive of the Sanitary Canal waters. (6862-6863.)

The Discharge of the Illinois River at Kampsville.

1889.

The discharge at the Kampsville dam on April 9, 1889, was 10,052 cubic feet per second, or 603,020 cubic feet per minute; on June 21, 1889, it was 31,068 cubic feet per second, or 1,864,080 cubic feet per minute, and on January 18, 1900, one day after the drainage canal was opened, the discharge was 33,295 cubic feet per second, or 1,997,700 cubic feet per minute, and indicates a flood condition in the Illinois at that time, and shows what an immense volume of water was passing down the Illinois River at the time that the Drainage Canal was opened on January 17, 1900. These figures are taken from the report of Major W. L. Marshall, who was in charge of the Illinois River improvement for the United States Government. (6664.)

The Discharge of the Illinois River at Peoria.

The volume of discharge at Peoria on March 18, 1903, at the time that Professor Van Ornum made his experiments, was 41,218.7 cubic feet per second, or 2,473,122 cubic feet per minute, which shows a very high flood condition in the Illinois River at points above Peoria, and with a mean velocity of the river

of 2.62 feet per second. On April 3, 1903, at Peoria, the mean velocity of the river was 1.88 feet per second, with a discharge of 25,839.4 cubic feet per second, or 1,550,364 cubic feet per minute. (6663.)

The volume of discharge on July 5, 1903, at Peoria, at a time immediately before Mr. Randolph made his float experiments, was 9,424 cubic feet per second, or 565,440 cubic feet per minute, and on August 22, 1903, was 8,713 cubic feet per second, 532,780 cubic feet per minute. (6663.)

Time of Flow Between Chicago and St Louis.

In a float experiment made by Professor Van Ornum of the length of time it would take floats to pass from the south branch of the Chicago River to opposite the waterworks intakes at the Chain of Rocks, St. Louis, it was given as ten and one-half days. This experiment was made at a time of high flood in the Illinois, wherein the floats were kept in the center thread of the channel during the whole route, and is a minimum time calculated by Professor Van Ornum for the floats to travel between the south branch of the Chicago River and the Chain of Rocks at St. Louis. The conditions under which this experiment was made will be a matter of subsequent discussion. (1734-1753.)

A like experiment was made by Mr. Randolph in July, 1903, wherein he estimated the time required for a float to pass from Lake Street in the City of Chicago to St. Louis at 18½ days. A comparison of these two experiments, based upon conditions as they obtain in the Illinois River, will be subsequently discussed at the proper time. (6667-6671.)

The Mississippi River.

Brainerd, Minnesota, is the first town of any importance on the Mississippi River, about one hundred miles above Minneapolis, having a population of between seven and eight thousand people. St. Paul and Minneapolis are distant from St. Louis

about 680 miles. (Vol. 7, page 7002.) Situated upon the Mississippi River, and sewering directly into said stream, are the following towns: Beginning with Brainerd, Minnesota, we have St. Paul and Minneapolis, with a combined population of 365,783; Red Wing, 7,525; Winona, 19,714; La Crosse, 28,895; Dubuque, 36,297; Galena, 5,005; Clinton, 22,698; Rock Island, Davenport and Moline, with a combined population of 71,996; Muscatine, 14,073; Burlington, 23,201; Fort Madison, 9,274; Keokuk, 14,641; Quincy, 36,252; Hannibal, 12,780; Louisiana, 5,134; Alton, 14,210. (See Vol. 7, page 7014.) All these towns lie upon the watershed of the Mississippi River, above St. Louis, in addition to the towns situated upon the tributaries of that river. In addition to the sewage from these cities, the population of towns of 500 or more upon the watershed of the Mississippi above Grafton is 1,839,586. (6664.)

The Mississippi River in its flow from Minneapolis and St. Paul to St. Louis, a distance of about 680 miles, has a fall of 414 feet. (7002.) The mean discharge of the Mississippi River at Grafton, based upon the reports of the Mississippi River Commission for the years 1838 to 1898, is 57,000 cubic feet per second, or 3,920,000 cubic feet per minute. (7010.)

Time Flow of Mississippi River from St. Paul to St. Louis.

Minneapolis and St. Paul are situated fifteen days' flow from St. Louis, based on the tabulated results published by the Mississippi River Commission. (7015.)

The Missouri River.

The Missouri River, which enters the Mississippi about six miles above the intake at the Chain of Rocks, has situated upon its banks the following cities: Omaha, including South Omaha and Council Bluffs, with a combined population of 154,000, situated 680 miles above the City of St. Louis; also Plattsmouth, population 4,964; Nebraska City, 7,380; St. Joseph, 103,000; Atchison, 15,700; Leavenworth, 20,700; Kansas City, 215,000;

Jefferson City, 9,664; St. Charles, 7,982. All of these cities sewer directly into the Missouri River, and all are situated above the St. Louis waterworks, located at the Chain of Rocks.

The cities of Kansas City, Kansas, and Kansas City, Missouri, are located 403 miles from the City of St. Louis. At Kansas City, Kansas, are located great slaughtering houses, rendering establishments and stock yards, and the time necessary for water to pass from Kansas City, Kansas, to St. Louis, was estimated by Dr. Teichmann at about four days (1510), and by Rudolph Hering at six and three-quarters days (7001). The population residing upon the watershed of the Missouri River, in towns of 500 inhabitants and over, amounts to 1,650,594. (6654 and 7014.)

Mean Discharges.

The mean discharge of the Missouri River, as given in the reports of the Mississippi River Commission, is 120,000 cubic feet per second. (7010.)

Fall of the Missouri.

The Missouri River is the steepest of the three rivers—that is, it falls from Omaha, at an elevation of 960 feet above sea level, to St. Louis, at an elevation of about 380 feet above sea level, making the distance of fall in about 680 miles 580 feet. (7002.)

Time of Flow Between Omaha and St. Louis.

Based on the tabulated results of the discharge observations of the Mississippi River and its tributaries and outlets, published by the Mississippi River Commission, for the years 1838 to 1898, the velocity of flow from Omaha, Nebraska, to St. Louis, was 11.6 days, and from Kansas City, Missouri, to St. Louis, at about 6¾ days. (7003.)

St. Charles.

All the sewers of the City of St. Charles drain into the Missouri River. The City of St. Charles is located upon the left

bank of the Missouri River, above where it empties into the Mississippi River. The distance overland from St. Charles to the business district of St. Louis is about sixteen miles, and by water it is about thirty-one miles to the intake, Chain of Rocks. The land upon which St. Charles is situated rises abruptly from the Missouri River and at a distance of about three or four blocks back from the river the elevation is about 100 feet or more above the stream. The drainage of the business district and of nearly all of the residence district flows direct into the Missouri River. The drainage of the remainder of the residence district is north to the Mississippi River, which is only six miles away. The streets run parallel with and at right angles to the Missouri River. The business is done on the first two streets parallel with and near the Missouri River. The population of St. Charles in 1890 was 6,161 and in 1900 it was 7,982, from the United States Census Report. St. Charles is not provided with a complete sewage system. There are four public sewers, ranging from three or four blocks in length to eight blocks in length, draining the business districts and portions of the most populous territories. Besides these there are many private sewers from the hotels and business houses leading to the Missouri River. On Main Street, which is parallel with and one block from the river, there are five hotels and one or two livery stables. There is a public hospital which can accommodate about twenty patients located four blocks from the river, which has a sewer on Clay street. (6863.)

St. Louis.

The City of St. Louis is situated upon the west bank of the Mississippi River, about 12 miles below the mouth of the Missouri, and about 38 miles from the mouth of the Illinois. It has a population of 575,238, according to the United States census of 1900.

Water Supply of St. Louis.

The water supply of the City of St. Louis is taken from the Mississippi River from an intake tower built 1,500 feet from the west shore of that stream. The water as it passes this intake consists of the combined waters of the Missouri, Mississippi and Illinois Rivers. The amount of mixing of these three waters will be a matter of subsequent discussion. After the water is pumped from the Mississippi River by means of pumps located at the Chain of Rocks, it is deposited in settling basins, some of which are located at the Chain of Rocks and others at Bissell's Point, where the old intake of the St. Louis waterworks was formerly located, and at a point in the river immediately below which the Merchants' Bridge spans the Mississippi. The sewage from the City of St. Louis is all diverted by sewers into the Mississippi River, and the garbage of the city, by means of floating barges, anchored to the banks of the stream, afford the facilities for wagons hauling garbage from its streets and alleys to dump the same into the stream as it flows past the City of St. Louis.

Settling Basins.

The settling basins of St. Louis retain the water from 36 to 70 hours, and while the water is in the settling basins there is some 70 per cent. of the bacteria removed, and this removal has extended as high as from 90 to 95 per cent. to the consumer after the water has passed through the settling basins and reservoirs of the City of St. Louis. (871.)

Wells in St. Louis.

In addition to getting its main public water supply through its public water system, there are located in the City of St. Louis 437 public wells on the streets, and in addition thereto there are 4,411 private wells scattered throughout the City of St. Louis. These wells are known to be contaminated, averaging

about one out of every five, but, notwithstanding the enormous number of contaminated wells existing in the City of St. Louis, as disclosed by the reports of its city chemist, as published in its public health reports, the Board of Health of the City of St. Louis, in 1895, refused to continue the examination of these wells, and condemned the same as a private water supply to be used by the citizens of the City of St. Louis. (6686.)

Population of the Three Watersheds Above St. Louis.

The Mississippi River, as it passes the St. Louis intake at the Chain of Rocks, where the water supply of the City of St. Louis is obtained, which consists of the combined waters of the Missouri, Mississippi and Illinois Rivers, has received, exclusive of the Sanitary District of Chicago, the sewage of a population of 4,089,931. The population situated upon the Missouri River is 1,650,549; the Mississippi, above Grafton, 1,839,586; the Illinois River, exclusive of Chicago, 599,751, and with the population of the Sanitary District of 1,698,575, gives the aggregate population of the Illinois River of 2,298,326. Prior to January, 1900, the population upon the three watersheds sewering into the Mississippi River which made up the Mississippi River at the intake at St. Louis amounted to an excess of 4,000,000 people. (6654.)

The State of Missouri.

The State of Missouri, the complainant in this cause, has situated within its jurisdiction the cities of Kansas City, with a population of 215,000; Jefferson City, with a population of 9,664; St. Joseph, with a population of 103,000; St. Charles, with a population of 7,892; Booneville, with a population of 4,377; Hannibal, with a population of 12,780; Louisiana, with a population of 5,131; St. Louis, with a population of 575,238; Cape Girardeau, with a population of 4,815, and all of these cities empty their unpurified sewage either into the Missouri or the Mississippi River within the confines of the State of

Missouri, thereby contributing to the pollution and infection of these watercourses.

Typhoid Fever in St. Louis.

The number of deaths reported in the public health reports of the City of St. Louis under the head of typhoid fever alone since 1890 to 1903, inclusive, are as follows:

1890, 140; 1891, 165; 1892, 441; 1893, 215; 1894, 171; 1895, 107; 1896, 106; 1897, 125; 1898, 95; 1899, 131; 1900, 168; 1901, 198; 1902, 222; 1903, 288. (6296.)

This mortality under the heading of typhoid fever alone does not correctly show the true typhoid conditions in the City of St. Louis, as will be shown at a subsequent part of this brief.

Typhoid Fever Deaths on Missouri River Watershed.

After a personal investigation of the typhoid fever deaths upon the Missouri River watershed by the representative of the complainant and the defendant, the number of typhoid fever deaths occurring from 1893 to 1902 upon the watershed of the Missouri River, in the towns of Lincoln, Nebraska; Omaha, Council Bluffs, St. Joseph, Missouri; St. Charles, Missouri; Kansas City, Missouri, and Jefferson City, to say nothing about the typhoid fever deaths which occurred in the rural communities upon this watershed, was disclosed by the statistics, as follows:

1893	139	1899	158
1894	127	1900	113
1895	123	1901	118
1896	89	1902	139
1897	97	(6901.)	
1898	118		

Typhoid Fever Deaths on the Mississippi River Watershed.

The number of typhoid deaths, secured in the same manner for the watershed of the Mississippi as was the statistics for the watershed of the Missouri, disclose that from 1893 to 1902 the

number of deaths reported to the different boards of health in the cities of St. Paul, Minneapolis, Red Wing, Winona, La Crosse, Dubuque, Clinton, Rock Island, Moline, Davenport, Muscatine, Burlington, Fort Madison, Keokuk, Quincy, Hannibal, Missouri; Louisiana, Missouri, and Des Moines, were as follows:

1893	321	1898	237
1894	285	1899	217
1895	240	1900	261
1896	200	1901	291
1897	257	1902	210

Typhoid Fever Deaths on the Illinois Watershed Exclusive of Chicago.

The total number of typhoid deaths reported upon the Illinois River watershed, as secured in the same manner as the statistics for the Mississippi and Missouri River watersheds, as found in the cities of Peoria, Bloomington, Springfield, Ottawa, Decatur, Joliet, Pekin, Elgin, Aurora and Havana, were as follows:

1893	45	1898	66
1894	62	1899	55
1895	45	1900	129
1896	66	1901	85
1897	56	1902	82

Typhoid Fever Deaths in Chicago.

The total number of deaths in the City of Chicago, as disclosed by its public health reports for the years from 1890 to 1902, inclusive, are as follows:

1890	1008	1897	437
1891	1997	1898	636
1892	1489	1899	442
1893	670	1900	339
1894	491	1901	509
1895	518	1902	801
1896	751	(6903.)	

These foregoing tables of statistics include all the reported deaths in the cities mentioned (but do not include the number

of deaths from typhoid in the rural communities and the many smaller cities lying tributary to the rivers in question) attributable to typhoid fever upon the three watersheds lying tributary to the St. Louis waterworks, situated in the Mississippi River at the Chain of Rocks, 1,500 feet from the Missouri shore, together with the deaths from typhoid fever, as the same are reported in the published reports of the City of St. Louis and the City of Chicago.

The cities lying tributary to the Missouri River and which empty their sewage, infected with typhoid dejecta, into the Missouri River, are as follows: beginning with Omaha, Nebraska, which is the most remote city in point of distance under consideration, and coming down the river to St. Charles, Missouri, which is the nearest city, with a population of about 7,000 inhabitants, within forty miles of the St. Louis intake: all of these cities are nearer, in point of time, to the intake tower of the City of St. Louis than is the City of Chicago, for the reason that the fall of the Missouri River, from Lincoln, Nebraska, to St. Louis, is down an incline 580 feet, which causes a swifter current, carrying the organic matter and the dangerous and infecting elements of the sewage from those cities on the Missouri watershed with greater rapidity, in point of velocity, and consequently with shorter time interval, if measured by time, than does the Illinois River, with its incline of 178 feet from the City of Chicago to the City of St. Louis, a distance of 357 miles, with a time interval much greater than that of the Missouri or the Mississippi from St. Paul to St. Louis. The Mississippi River has a fall of 414 feet from Minneapolis to the St. Louis intake, and a time interval of ten and one-half days. Between Omaha, Nebraska, and St. Louis, upon the Missouri, are situated cities of varying distances from the intake tower at St. Louis, emptying their sewage into that stream, which sewage carries with it the typhoid dejecta from the people which, according to the statistics hereto presented, died of typhoid fever, together with those who recovered from the disease. The same is true for the Mississippi River, all of

which places are nearer, in point of time, to the intake tower of the City of St. Louis than is the City of Chicago.

The defendant contends that in view of the fact that the Missouri River watershed has typhoid fever dejecta emptying into the Missouri River, and the Mississippi River watershed likewise contributes typhoid fever infection to the Mississippi River, and the Illinois River watershed, exclusive of the Sanitary District of Chicago, also contributes typhoid pollution and infection to the Illinois River, the combined waters of these three rivers forming the Mississippi River, from which the City of St. Louis takes its water supply at its intake at the Chain of Rocks, that it is not within the bounds of reason or within the ability of expert testimony to establish beyond all reasonable doubt that, assuming that the typhoid condition in the City of St. Louis is properly disclosed by its public health reports, under the heading of typhoid fever deaths, that the Sanitary District of Chicago is the direct, immediate and approximate cause for the typhoid fever existing in St. Louis since January, 1900, or that the Sanitary District of Chicago is responsible for any increase in typhoid fever that may obtain in the City of St. Louis since 1900, as evidenced by the reports of typhoid deaths as published in the public health reports of the City of St. Louis. By no process of reasoning can the contribution of infection from the Missouri River, the Mississippi River or the infection from wells, milk supplies, and other local causes or the Illinois River, exclusive of Chicago be eliminated from this problem.

The defendants in this case deny:

1. That there is any increase of typhoid fever in the City of St. Louis since the opening of the Drainage Canal over conditions which obtained prior to January, 1900, attributable to the opening of the Sanitary District channel.

2. That the sewage from the Sanitary District is responsible in any manner, directly or indirectly, in whole or in part, for the typhoid conditions existing in the City of St. Louis since the opening of the Drainage Canal.

3. That the water supply of the City of St. Louis as evidenced by its public health reports was a good and safe water supply to be used for drinking and domestic purposes, prior to January, 1900, or that it was a fit water supply as treated by the settling basins of St. Louis to be used by the citizens of St. Louis for drinking and domestic purposes.

4. That by virtue of the opening of the Drainage Canal the citizens of Missouri living upon the west bank of the Mississippi River taking their water supply from the Mississippi River have been injured in any way by virtue of the opening of the Drainage Canal.

5. That the health of the citizens of Missouri or of the City of St. Louis has been injured in any degree, directly or indirectly, by the opening of the Drainage Canal and the flowing of sewage from that channel into the Desplaines and Illinois Rivers.

6. That by virtue of the opening of the Drainage Canal that the waters of the Mississippi River as the same pass along the shores of the State of Missouri have been injured for drinking, domestic, agricultural or mechanical purposes for use by the citizens of that State.

7. That the Illinois River either before or since the opening of the Drainage Canal has been the means of conveying disease germs into the Mississippi River or to the citizens of Missouri taking their water supply from the Mississippi River.

8. That the opening of the Drainage Canal and flowing the sewage from the Sanitary District into the Desplaines and Illinois Rivers has influenced or will influence in any degree the cost of installation, maintenance or operation of an effective filtration plant at St. Louis.

9. That there is any evidence in this case justifying the assertion that a typhoid germ entering the sewers of Chicago will survive the journey through the Chicago River, the Drainage Canal, the Desplaines River, the Illinois River and the Mississippi River and the intake tower and settling basins and water mains at St. Louis in a live and virulent condition.

10. That the so-called Detroit epidemic, Washington epidemic, and Covington epidemic as relied upon by complainants in this case have been proved to be due to conveyance of typhoid bacilli in water from relatively distant points as alleged in the opinions given by complainant's witnesses; the facts on the contrary as disclosed by the evidence lend no support to the hypotheses and inferences of complainant's witnesses.

The foregoing statements of facts made by defendants have been established overwhelmingly by the evidence in this case.

In support of the foregoing propositions the defendants have placed upon the witness stand men of eminent qualifications, deep research and original investigations, who hold high positions in our colleges and universities throughout the country, and their testimony sustains, establishes and supports every contention made by the defendants in this case.

The witnesses whom defendants called, and their qualifications, are as follows:

II.

QUALIFICATION OF WITNESSES.

Professor John H. Long,

Called as a witness by defendants, qualified as follows:

I have been a teacher of chemistry in the Northwestern University of Chicago for twenty-two years. Prior to that time I taught in Wesleyan University at Middletown, Connecticut, for one year, and for seven years prior to that I was engaged in the study of chemistry. Studied chemistry for four years, from 1873 to 1877, in the University of Kansas, and from 1877 to 1880 in the German Universities of Tuebingen, Wuerzburg and Breslau. Was born near Steubenville, Ohio. I am a member of a number of the American and Foreign Scientific Societies, and have been president of Section C of the American Association for the Advancement of Science, and at the present time I am president of the American Chemical Society. The American Chemical Society is an organization of American chemists, made up largely of professional men and teachers in the various institutions, and industrial chemists, with a membership of about 3,000. I have written several books in general on analytical chemistry. I am translator of a law German work on optical chemistry. My work in chemistry has been mainly in the line of sanitary and medical, of physiological chemistry. I mean by sanitary chemistry what has to do, in a general way, with the question of public health. That is, examinations of water and air and food supplies of all kinds. For a number of years I was chemist of the Board of Health of Chicago, between 1885 and 1890. Since 1885 I have been chemist of the Illinois State Board of Health, and the work that I have done for the Illinois State Board of Health has been almost wholly in the line of water examinations. I have made in addition to these, some examinations of poisons for the Board, but the work has been very largely the examination of

water. I have made a special study of water analyses, and I took up the study while I was a student, but practically in an experimental way after coming to Chicago, and in the summer of 1882 I made the first practical examinations. I was connected for five years with the Chicago Board of Health. The first examinations I made of water in Illinois were in connection with the study of Lake Michigan, beginning in 1882. I made numerous tests of water from the various pumping stations, beginning with Evanston on the North, and Chicago Avenue, and later from the Hyde Park stations. I am acquainted with the Illinois and Michigan Canal as far back as 1883. Have made chemical surveys of the Illinois River in 1886, 1887, 1888, 1889, 1890, 1891, 1899, 1900 and 1901. (See Vol. 4, pp. 3984, *et seq.*)

Professor F. Robert Zeit,

Called as a witness by the defendants, qualified as follows:

I live at 4016 Vincennes Avenue, Chicago. Am a teacher at Northwestern University Medical School and Post-Graduate Medical School of Pathology and Bacteriology. Have been connected with that school for five years. My early education was received in Switzerland and Germany, and my medical degree is from the Western Reserve University at Cleveland, Ohio. I was afterwards, three years, with Professor Klebs, and when he opened his laboratory here in the city I was instructor under him for three years. Professor Klebs is one of the noted bacteriologists. For twenty-five years he was teacher of pathology and bacteriology at German, Swiss and Austrian Universities, and was induced to come to this country, and was here five years in all. He was called to Rush Medical College as professor of pathology. From there I was called to the Northwestern University as a teacher in bacteriology. After one year I was made professor of bacteriology at the Northwestern University Medical School, and one year or more ago I was given one whole department of pathology and bacteriology. I made bacteriological examinations in 1900, 1901 and 1902 for the Sanitary District upon the Chicago River,

Drainage Canal and Illinois River, etc. (See Vol. 5, pp. 4396, *et seq.*)

Doctor Adolph Gehrmann,

Called as a witness by the defendants, qualified as follows:

I am a physician and bacteriologist. From the year 1893 I was connected with the Chicago Department of Health in the capacity of bacteriologist and microscopist for the milk department during 1893, and from January, 1894 until June, 1902 as a director of the laboratory and bacteriologist of the department. I received the ordinary high school education in Chicago and entered the Chicago Medical College, the medical department of the Northwestern University and was graduated with degree of Doctor of Medicine in 1890. Since then I studied in this country and, to some extent, abroad. I have taught bacteriology and hygiene in the College of Physicians and Surgeons of Chicago, which is the medical department of the University of Ilinois. I am also connected as professor of hygiene in the Dearborn Medical College of Chicago, and as professor of bacteriology in the Harvey Medical College in Chicago. In 1899 I made a bacterial survey of the waters of the Illinois and Michigan Canal, the Desplaines River, the Illinois River, and tributaries, the Mississippi and Missouri Rivers, and attended a number of conferences with Professors Palmer and Burrill of the University of Illinois, and Professor Jordan of the University of Chicago. (See Rec. Vol. 5, pp. 4744.)

Mr. D. B. Bisbee,

Called as a witness by the defendants, qualified as follows:

I reside at La Grange, Illinois. I am a chemist. I graduated from the Agricultural College of Iowa. I took the full course, four years, and then took a post-graduate course afterwards. For four years, beginning in February, 1896, I was the assistant city chemist of Chicago, and was engaged at that time in water analyses. I made water analyses before I became city chemist. I was familiar with the subject, and since

1900 have been chief chemist of the City of Chicago, and the water examination has been under my direction. I have averaged seven samples a day for six days a week, covering a period of four years. (See Vol. 5, pp. 4875.)

Professor Arthur W. Palmer,

Called as a witness by the defendants, qualified as follows:

I am professor of chemistry in the University of Illinois. I have held that position for fourteen years. I was educated in the public schools of Illinois, at the University of Illinois, at Harvard, at Berlin and Goettingen, in Germany. At the University of Illinois I took a course of chemistry for four years. At Harvard I studied chemistry two years, from 1884 to 1886, and I studied chemistry at Berlin and Goettingen in 1888 and 1889. I have had experience as an assistant instructor in chemistry for the years 1883 and 1884, as an instructor in the years 1886, 1887 and 1888, and during the last fourteen years as professor of chemistry in the State University. I teach the practical analyses of water. I have personally engaged in making chemical analyses for about twenty-two years as a student and as investigator. I took the degree of bachelor of science in chemistry at the University of Illinois in 1883, and the degree of doctor of science in chemistry at Harvard in 1886. Have frequently made chemical analyses of the Illinois River during the last fifteen years. (See Rec. Vol. 5, page 4903.)

Professor Thomas J. Burrill,

Called as a witness by the defendants, qualified as follows:

I live at Urbana, Illinois. I am a member of the faculty of the University of Illinois. I hold the position of professor of botany. I was educated at the Illinois State Normal University, and I studied biology. I left that institution in 1863. I have pursued my studies continuously since that time in the larger field of botany, but more especially cryptogamic botany, and more especially, still, the group of fungi in which we class

the bacteria. I took up the subject by myself, as I was forced to do at that day, and at my home in Urbana largely, and elsewhere in the country as I could find opportunity. I have been engaged in teaching at the University of Illinois thirty-five years. I began studying bacteriology in 1877. I began teaching classes in bacteriology in 1865. All of my time has been devoted to teaching and investigating biology, which includes bacteriology. I have delivered lectures before the American Association for the Advancement of Science, beginning in 1880 upon bacteriological subjects and for a number of years subsequent to that time, for the same society. I gave a course of lectures before the Natural History Society of Peoria. Since 1878 I have had annual papers in the proceedings of the American Microscopical Society. I have had some papers in the proceedings of the Royal Microscopical Society of London, England, and a great number of the more practical branches of my subject before the State Agricultural and Horticultural Associations. I am a member of the American Association for the Advancement of Science, American Microscopical Society, of which I am at present president, and the Western Naturalist Society. The Northwestern University at Evanston conferred upon me the Master of Arts degree. The old Chicago University, upon the thesis bacteriological, in kind, in 1881, conferred upon me the degree of Ph. D., and the Northwestern University, in 1893, conferred upon me the degree of L. L. D. I have never published anything upon the examination of water on my own investigations until the article appeared in the report of "Streams Examination." (See Vol. 6, p. 5711.)

Professor Edwin Oakes Jordan.

Called as a witness by the defendants, qualified as follows:

I am instructor at the University of Chicago and live in Chicago. I have been connected with the University of Chicago since the opening of the University. That is eleven years ago. I am associate professor of bacteriology. I first held the posi-

tion of associate, then I was advanced to instructor, and then to assistant professor. I have been associate professor since 1900. I graduated in 1888 from the Massachusetts Institute of Technology, then for a time I studied at the College of Physicians and Surgeons in New York, following which, for nearly two years, I was in the employ of the Massachusetts State Board of Health, in connection with work being done at the Lawrence Experiment Station. After that I went to Clark University at Worcester, Massachusetts, for graduate work, and took my Doctor of Philosophy degree there in 1892, and was there until I came to Chicago. I did some work in bacteriological water analysis in the laboratory at the Massachusetts Institute, under the direction of Professor Sedgwick. I also made collections of water from the various filtration tanks at the Lawrence Experiment Station. I did some work at the station and was at Lawrence for a time in connection with that work. Mr. Hazen had charge of the chemical work at that time, and I had the bacterial. I have done work as a student in chemistry, and I have done some work on sanitary water analysis since graduating from the institute. I am generally familiar with sanitary water analysis. I did work on this subject at the Institute of Technology, and I have also done some work at the University of Chicago. I have taught public hygiene at the University of Chicago for several years, and in lecturing on that subject I have had to deal with the classic epidemics in this country and abroad. I have also studied several epidemics at first hand. I was at Lowell for a short time with Professor Sedgwick, at the time he investigated the epidemic of typhoid fever in that city. Since that time I have visited Stamford, Connecticut, where there had been an epidemic of typhoid fever, attributed to infected milk, I believe several hundred cases. More recently I have visited Ithaca, New York, been over the watershed of the stream supplying that town, and examined the various sources of supply, as well as the statistics of typhoid fever at the time

of the recent epidemic. I am familiar with the different classical epidemics, and have frequently used such literature for the purposes of instructing my classes. In connection with my work on public hygiene and epidemiology, the subject called Sanitary Science has necessarily been considered. I have given special attention to what is known as bacteriological sanitary science, including epidemiology and water chemistry. I have made analyses of the Illinois River. There are three periods of time, one extending from April or May, 1899, to the end of the year; the second period extending from the 1st of January, 1900, to the end of June, 1900, and the third period from October, 1901, to about the 1st of January, 1902. Have also investigated the typhoid epidemic at Butler, Pennsylvania. (See Vol. 6, page 5805.)

Mr. Norman Macleod Harris,

Called as a witness by the defendants, qualified as follows:

I am employed as an assistant in the Chicago University. Associate in bacteriology under Professor Jordan. Have been there since June. Prior to that time I was associate in bacteriology at Johns Hopkins University, from October, 1897, to May, 1903, under Professor William H. Welch. Am a graduate of the University of Toronto. I took a post-graduate course in London, England. I obtained the diploma of the Royal College of Physicians of London. I did some work under the direction and supervision of Professor Jordan for the Sanitary District of Chicago, in connection with an experiment made in the Drainage Canal on the typhoid bacilli. (See Vol. 7, pp. 6403.)

Mr. Ernest E. Irons,

Called as a witness by the defendants, qualified as follows:

I am assistant in the University of Chicago in bacteriology, under Professor Jordan. I graduated from the University of Chicago in 1900. After graduating I was assistant with Professor Jordan in bacteriology. I did work under the direction

and supervision of Professor Jordan in connection with Streams Examination in 1899 and 1900 at the University of Chicago. This work was done in connection with the examination of the waters of the Illinois, Mississippi and Missouri Rivers, and is published in what is known as "Streams Examination" by the Sanitary District. (See Vol. 7, p. 6405.)

Doctor Victor H. Bassett,

Called as a witness by the defendants, qualified as follows:

I graduated from Knox College in 1896 at Galesburg, Illinois. I took up scientific work in the University of Wisconsin, beginning in 1896. For the first two years I was assistant in chemistry under Doctor Daniels, and the following year I became assistant to Doctor Russell, and remained with him one year. After leaving the University of Wisconsin, I went to Johns Hopkins Medical School at Baltimore, and remained there four years. I took the medical course and acted as an assistant at the same time, under Doctor Harris, in Doctor Welch's pathological laboratory, specially in the place of what they call a student assistant. During the two years I was there I acted as bacteriologist to the Thomas Wilson Sanitarium, where children who have summer diarrhea are cared for. Following my graduation in June I spent another summer at the sanitarium, and on the 1st of October became assistant to Professor Zeit of the Medical College of the Northwestern University. (See Vol. 7, pp. 6457.)

Professor H. L. Russell,

Called as a witness by the defendants, qualified as follows:

I reside at Madison, Wisconsin. I am in charge of the department of bacteriology in the University of Wisconsin. I received my bacteriologist degree from the University of Wisconsin in 1888, and remained there as fellow of bacteriology until 1890, and then went to Europe and studied in Koch's Institute in the University of Berlin, in the Zoological Station at Naples

and in the Pasteur Institute at Paris. I returned to America in 1891, and took my Ph. D. degree at Johns Hopkins University. And in 1893 I assumed professorship in the University of Wisconsin at Madison. I have been connected since 1894 with the Wisconsin State Board of Health as bacteriologist, and in that capacity, as well as in a private capacity, I have had to do with the analysis of water from a bacteriological point of view for sanitary purposes. I have had the examination of all the waters which were submitted for public analyses in the State since that time, and have been engaged especially in the examination of the water supplies of the cities of Superior, Ashland, Marinette, Menominee, Merrill, Stevens Point, Warsau, Eau Claire, Portage, Green Bay, Beloit, Baraboo, and Dubuque, Iowa, besides a number of smaller places. In connection with this work I have carried out investigations on the sanitary nature of waters. I have studied a very severe outbreak of typhoid fever in Baraboo in the year 1901, and I had the examination of the waters at the time of the typhoid outbreak in Ashland, and just subsequent to the typhoid outbreak in Superior, Wisconsin, also in Menominee, Michigan, and Marinette, Wisconsin. I am acquainted with the literature bearing upon epidemics relating to water borne diseases. In connection with water borne diseases I have studied the literature with reference to outbreaks caused by Asiatic cholera, organisms producing gastro-intestinal diseases, dysentery and also anthrax. In connection with the work previously mentioned it has been necessary for me to make bacterial examinations of waters in large numbers. I have not studied from a laboratory point of view the chemical side of it so much, but I have given special attention to bacteriology. In the course of our sanitary work in the State waters are received by me. Samples of the same are taken out for bacteriological analysis, and the balance of the samples turned over to the State chemist. His report comes to me merely as a chemical report without any interpretation, and it has been necessary for me to combine the results of the bacteriological and chemical examinations and give a

proper interpretation of the co-ordinate methods of analyses. I have studied the bacterial and chemical analyses of the waters of Lake Michigan, the Drainage Canal, the Desplaines River, the Illinois River, the Mississippi River and the Missouri River, as made by Professor Jordan, Gehrmann, Palmer and Burrill, the same being published in what is known as "Reports of Streams Examinations," published by the Sanitary District of Chicago. In September, 1903, I made a trip, in conjunction with a number of other individuals from Chicago to St. Louis, by way of the Drainage Canal, Desplaines River, Illinois River, Mississippi River, and had given me special opportunities for the physical examination of those streams. This trip was made by boat from Chicago to Lockport. We went by rail from Lockport to Joliet and from Joliet to Peoria on the Rock Island, and then took the Fish Commissioner's Steamer, Illinois, at Peru, stopping en route during the night so as to give an opportunity for the physical examination of the stream throughout its entire course by daylight. (Vol. 7, p. 6467.)

Mr. Isham Randolph,

Called as a witness by the defendants, qualified as follows:

I am a civil engineer. I began that line of work in 1868. I am not a graduate of any technical institution of engineering, but have gathered my engineering knowledge from practice, observation and study. In 1868 I entered the service of the B. & O. Railroad Company as an axman, on the Winchester and Strausberg extension of that line. I remained with that road in the capacity of axman, and later as rodman, until its completion in 1870. In 1870 I went to the Washington and Ohio road as leveler, and surveyed from Round Hill in Louden County, through the mountains to Winchester, Virginia. After the surveys and estimates were completed I went into the service of the Lehigh Valley Railroad, locating the extension of that line from Jugtown Mountain to Perth Amboy, New Jersey. My next engagement was with the B. & O. Railroad. I entered

their service in March, 1872 as transit man, on the survey from Syracuse, Indiana, to Chicago. I had charge of the locating party on that line, located 110 miles of the road, later building 27 miles of it and building the round house and shops of that company at South Chicago. After the completion of that work engineering was pretty dull, and the best thing I could get was bookkeeping and draftsman in a plumbing shop in Richmond, Virginia, and I stayed there until the 1st of January, 1876, when I was invited to a position as assistant engineer on the Scioto Valley Railway in Ohio. After the completion of that road I was its roadmaster. In 1880 I was offered the position of chief engineer of the Chicago and Western Indiana and the Belt Railway of Chicago. I took charge of that work on the first day of May, 1880, and remained with the company for four years. I then opened an office for general engineering work in Chicago, and in 1886 I went into the service of the Illinois Railroad Company to locate and build the Chicago, Madison and Northern Railroad, and the Freeport and Dodgeville Railroad. After that work I opened an office in Chicago, in 1888, and did general railroad and municipal work. I was consulting engineer for the B. & O., for the Union Stock Yards and Transit Company, the Chicago and Calumet Terminal Railroad Company, and for the Stickney project and transfer yards. In 1893 I was tendered the position of chief engineer of the Sanitary District of Chicago. Was elected to that office on the 7th day of June of that year, and have continued as such engineer ever since. In 1893 and 1894 I was the president of the Western Society of Engineers. (See Vol. 7, pp. 6607.)

Professor Ludwig Hektoen,

Called as a witness by the defendants, qualified as follows:

I am a physician and surgeon. I am a graduate of the College of Physicians and Surgeons of Chicago. I served as an interne in the Cook County Hospital for eighteen months, and I served as physician to the coroner's office

of Cook County for three years. In that capacity I made post-mortem examinations, as required by the coroner. During that time I made several hundred post-mortems. The exact number I do not know. After leaving the coroner's office I became connected with Rush Medical College. Have been there about eight years as professor of pathology. I am connected with the University of Chicago as professor of pathology there also. Have been connected there for about four years. My time is devoted to investigations principally in connection with infectious diseases, such as scarlet fever. During the last two or three years my work has become limited in this way especially. I have made autopsies in connection with my work at the County Hospital, in order to study the changes produced by disease during life. The work there includes pretty much all sorts of diseases that are likely to appear in a hospital of that sort. The County Hospital is a large hospital, and I have done the larger share of the post-mortems there for many years, about ten or twelve years. I have made a special study of the so-called germ diseases. I studied typhoid fever and malarial fever from the standpoint of a pathologist and clinician. (Vol. 7, pp. 6707.)

Professor E. G. Hastings,

Called as a witness by the defendants, qualified as follows:

I am instructor and investigator in bacteriology in the University of Wisconsin. I have been there since July, 1899, with the exception of one year, in which I was studying in Germany, at Munich. I graduated at the Ohio State University, and am assistant professor in the University of Wisconsin under Professor Russell. (Vol. 7, pp. 6716.)

Professor Erastus G. Smith,

Called as a witness by the defendants, qualified as follows:

I am now professor of chemistry at Beloit College, Beloit, Wisconsin. I have been there since 1881. I graduated from

Amherst College in 1877 with the degree of A. B. After graduating I studied medicine for a year under the private tutelage of Doctor A. F. Reed of Massachusetts. I was then called as instructor in chemistry to Williston Seminary, East Hampton, Massachusetts. I was there three years, and from there I was called to the professorship of chemistry and mineralogy at Beloit College. I have been there ever since except for an absence of about eighteen months, when I was in Europe studying at the Georgia Augusta University in Germany, where I took my degree of Doctor of Philosophy in August, 1883. In Europe I studied chemistry and mineralogy. I took a course in bacteriology one summer at the Massachusetts Institute of Technology in Boston. I have pursued the study of bacteriology since. I have a laboratory of my own, a private laboratory, known as Beloit Sanitary Laboratory, where studies of this kind are carried out. It is particularly devoted to studies of this character. I have not taught bacteriology. I have given practically all my available time since about 1885 to the study of sanitary problems, especially water courses. In the course of my studies and investigations I have been called to the study of many public water supplies, including the study of supplies from the ground or ground wells, or artesian wells, rivers and lakes and impounded reservoirs. These would naturally include the lakes and rivers and streams tributary thereto. I have also done considerable work upon the Platte River, the Missouri River, the Mississippi River, the Schuylkill River, the Delaware River, Beaver River, Pennsylvania, and other smaller streams. The work done upon these streams has been the observation of the sanitary qualities of the water and its adaptability for drinking and domestic purposes and its suitability for water supply. These embraced both chemical and bacterial work, the bacteriological work having been done the last six or seven years. Before that most all, practically all of it, was chemical work. I have devoted about all of my available time since about 1885 to this class of problems. I have investigated the typhoid fever epidemic at Baraboo, Wisconsin, Ash-

land, Wisconsin, West Superior, Wisconsin, Menominee, Michigan, and Rock Island, Illinois, and have frequently been called in where typhoid fever was alleged to be present. In the prosecution of my sanitary work I have had a great deal to do with different systems of filtration. In fact I have done work upon filtered systems, of one sort or another at Davenport, to which water company I have acted as consulting chemist for ten or twelve years, with the filter plant at Rock Island, with the filter plant at Ashland, at Independence, Kansas, at Burlington, Kansas, Cedar Rapids, Iowa, at Beaver Falls, Pennsylvania, at Warren, Ohio, at Brooklyn, New York, Binghampton, New York, Denver, Colorado, Kankakee, Illinois, Eau Claire, Wisconsin, Oshkosh, Wisconsin, West Superior, Wisconsin, and at Burlington, Iowa. I have been consulted upon the systems of filtration introduced at Burlington, Iowa, the system at New Brighton, Pennsylvania, and at Ashland. The whole matter of filtration at Menominee has been up under advisement. The readjustment of the plant at Cedar Rapids. Working over the plant at Oshkosh, Wisconsin, where they had an alarming outbreak of typhoid fever a few years ago. I also made a report upon the proposition of establishing a filter plant for the City of Minneapolis, Minnesota and elsewhere. I have investigated the systems of filtration at London, Paris, Antwerp, Berlin, and Hamburg. I have studied the literature bearing upon typhoid fever epidemics of this country. I am acquainted with the literature in regard to the epidemic at Plymouth and Lowell. I have devoted practically all of my available time to water analyses since 1885. The study of water supplies, their purification when necessary, and the adaptability to public use has been the branch of sanitary science that I have given special attention to. That study includes especially the study of the interpretation of the analyses and their significance from a sanitary standpoint. I have also at Beloit installed a private laboratory which is given up practically wholly to the study, and is known as the Beloit Sanitary Laboratory, and I have kept an assistant for some years, working all the time, practi-

cally upon problems of this kind. In the course of this work we have made about ten thousand analyses of water. Under my direction another laboratory was established in 1896 or 1897 at Denver, Colorado, where we made in three years about six thousand analyses of waters. These were mostly bacteriological analyses. I have examined carefully the report of Streams Examinations, published by the Sanitary District of Chicago. I know the Chicago River, the Drainage Canal, the Desplaines River, the Illinois River, the Mississippi from Grafton to St. Louis. In the course of my professional work in the study of the sanitary character of water supplies I have from time to time carried out researches and surveys upon the Mississippi River, the same extending over a period of at least twelve years. The first place where I made an examination was at Brainard, Minnesota. The next point on the river which I had occasion to examine was at Minneapolis, Minnesota. The next place upon the river which I made an examination for is St. Paul. The next city upon the river was the town of Winona. The next point upon the river which I examined and have studied is that of Dubuque, Iowa. The next place upon the river where I have made examinations and study is at Clinton, Iowa. The particular point where I studied the river is at Davenport, Iowa. Another point upon the river which I have studied is Rock Island, Illinois. The next point upon the river is Muscatine, Iowa. Also Burlington, Iowa. I have been asked by the Pure Water Commission at Keokuk, Iowa, to investigate their water supply. I have also made examinations of the water at Quincy, Illinois. I acted as chemist to the American Waterworks Company, operating a public water plant at the City of Omaha, and I made a series of analyses of the Missouri River for that company, the same extending over a period of about three years. I have acted in the same capacity for about two years for the water company at Council Bluffs, Iowa. (Vol. 7, pp. 6736 to 6790.)

Mr. Jacob A. Harmon,

Called as a witness by the defendants, qualified as follows:

I reside at Peoria, Illinois. I have been a civil engineer since 1887. I graduated at the Normal University at Lebanon, Ohio, and took the engineering course there. The first two years after graduation I was doing country surveying and drainage engineering and in 1890 I went to Peoria and was assistant engineer in the construction of the waterworks there for about a year and a half, and the beginning of 1892 I established an office in Peoria for general engineering practice—civil engineering—and then in 1893 I was appointed city engineer of Peoria and continued in that position for two years, and since that time I have been doing general civil engineering work, water supply, sewerage and drainage and general surveying. For the last five years I have been consulting engineer to the State Board of Health of Illinois. (See Vol. 7, p. 6846.)

Mr. Robert Spurr Weston,

Called as a witness by the defendants, qualified as follows:

I am a graduate of Amherst College in 1891. After graduation I was employed as chemist for about three years with the American Sugar Refining Company, and also on a plantation in Louisiana. After that I was a student in the Massachusetts Institute of Technology, and in the University of Berlin, and besides that I have been a volunteer worker in the laboratories of the Massachusetts and the German Imperial Boards of Health. Since then I have been engaged in sanitary work. In 1895 I was connected with the Louisville water purification experiments and subsequently have been connected with water purification experiments at West Superior, Wisconsin, at Washington, District of Columbia, and other places. In 1900 I was in direct charge of the water purification station at New Orleans and conducted an investigation lasting eight months as to the feasibility of purifying the Mississippi River water. I have been in private prac-

tice exclusive of this last period for six years. (Vol. 7, p. 6869.)

Professor W. P. Mason,

Called as a witness by the defendants, qualified as follows:

I am professor of chemistry in the Rensselaer Polytechnic Institute at Troy, New York. I have been with the faculty of the Rensselaer Polytechnic Institute for over twenty years. I have been there in the chemical department as professor of chemistry, and previous to that as assistant professor in chemistry. I have made a special study of water analysis. I have given especial attention to the examination of potable water, especially for city supply. I have had experience in the interpretation of chemical analyses of water. I have made a special study of sanitary problems as related to water supply. I am the author of books entitled "Water Supply," published by John Wiley & Son, and "Examination of Water," published by the same firm. As an expert I have reported upon and testified in legal cases regarding the water supply of cities or towns of the United States, such as New York, Brooklyn, Philadelphia, Washington, Columbia, Greenville, South Carolina; Danville, Virginia; Birmingham, Alabama; Meridian, Mississippi; Denver, Colorado; Indianapolis, Indiana; Duluth, Minnesota; West Superior, Wisconsin; Buffalo, New York; Elmira, New York; Albany, New York; Troy, New York; Cohoes, New York; Newark, New Jersey; Newburg, New York; Waterville, Maine; Waterford, New York; Providence, Rhode Island; Bath, Maine; Rensselaer, New York; Erie, Pennsylvania; Hot Springs, Arkansas; Atlantic City, New Jersey; South Hampton, New York; Burlington, Kansas; and sundry others that I cannot remember. I have examined the water supplies of Paris, Hamburg, Copenhagen, London, Liverpool, Hague, Stuttgart, Lubeck, Amsterdam and sundry others. I am acquainted with the literature bearing upon typhoid fever epidemics. I refer in that answer to both American and foreign typhoid fever epidemics. I am familiar with the literature thereupon. I have in the instances of water examinations to which I have already testified, some questions

involving typhoid fever arose therein, as for instance Bath, Maine; Cohoes, New York; Albany, New York; Buffalo, New York; Waterville, Maine; and possibly one or two others. I do not remember which ones now. I am acquainted with Asiatic cholera in Sicily and Italy, more particularly at Messina. That was a personal study, not during the time of the cholera outbreak. I was not there then, but I visited the place in order to obtain the information of an epidemic which was past. I have studied the tables as they appear in "Streams Examinations." I am acquainted with the Chicago River, the Drainage Canal, the Desplaines River, the Illinois River and the Mississippi River from Grafton to St. Louis. I went on a boat from the water front to Lockport down the Drainage Canal by daylight to St. Louis. (See Vol. 7, p. 6903.)

Mr. Rudolph Hering.

A witness called by the defendants, qualified as follows:

I am a hydraulic and sanitary engineer. My place of business is in New York City. The firm is Rudolph Hering and George W. Fuller. I took the course in civil engineering at Dresden, Germany, in 1867. After graduating I came home and started my engineering work in Brooklyn on Prospect Park, and then went to Philadelphia, on Fairmount Park, and in 1872 I was employed on the geological survey of the Yellowstone National Park, and in 1873 went back to Philadelphia, where I was first assistant engineer in the department in charge of bridges and sewers until 1880. In 1880 I went to Europe, commissioned by the National Board of Health, at Washington, to make an examination of and to report on European sewerage systems. I spent almost a year on that work, largely on my own account, studying also questions of water supply and other municipal problems. I visited all the large cities of England, France, Germany and Austria. I made a report to the National Board of Health as a result of that visit. It was in the "Annual report of the Board for the year 1881." I then acted as engineer for a number of cities in an advisory

capacity or as designer or constructor of works. From 1887 to the spring of 1886 I was engaged by the city of Philadelphia to make investigations for a new water supply for that city, and incidentally also for a number of other smaller cities. In 1882 I was engaged by the city of Cleveland to make a plan of sewerage for the intercreption of the sewage and cleansing the Cuyahoga.

After the Philadelphia work was completed the Mayor of Chicago, Carter H. Harrison, employed me to come here as chief engineer of the drainage and water supply commission and I stayed here about two years.

Then I was appointed consulting engineer for the sewerage works of New York City by the commissioner of public works and stayed there two years, and since that time I have been engaged by a very large number of cities in the United States and Canada, and also outside, in making plans and designs for sewerage and water supply works. In Philadelphia I was on a commission to report on the new water supply and recommended filtration of the water, which is now being carried out. Our commission made the general plans and the detail plans and specifications were carried out by Mr. John W. Hill, who is now the chief engineer of the filtration bureau. I then made a report for the city of Baltimore, also on a commission for the sewerage of that city.

I also made a report at the request of President Harrison, as chairman of a commission to devise a system of sewerage and drainage for the city of Washington, which is being carried out.

I have also been connected with the city of New Orleans for ten years on their works, for a sewerage, drainage and water supply, and I am acting now as consulting engineer. I was also consulting engineer for the city of San Francisco on their sewerage system, the plans for which were adopted.

I have also been consulted in other cities, making a report quite recently on the water supply of Pittsburg, Pennsylvania, together with Colonel A. M. Miller, U. S. A., and Mr. John W. Hill, Philadelphia.

I have also made reports on sewerage and water supply works for four or five cities in Canada, St. John, Toronto, Winnipeg and Victoria, and also for Honolulu, Hawaiian Islands, and for Santos, Brazil. (See Vol. 7, p. 6975.)

Mr. Albert S. Crane.

Called as a witness by the defendants, qualified as follows:

I am a civil engineer, a graduate of Cornell University. I spent the summer of 1891 with Mr. Hering in Europe, visiting sewage purification and water filtration works principally. Afterwards I went to work with the city engineer of Newton, Massachusetts, and occupied various positions from inspector to assistant engineer and finally division engineer. In December of 1894 I went to Washington and was engaged in the United States Engineer's office on sewerage plans for Fort Monroe.

In April, 1895, I accepted a position as assistant engineer in the Department of Sewers in the city of Brooklyn, and remained in that department and the Department of City Works until October, 1898.

From October, 1898, until March, 1900, I was chief assistant engineer of the Michigan & Lake Superior Power Company, situated at Sault Ste. Marie, Michigan. The first two years I was on water power construction. The last two years I was chief engineer of the Lake Superior Power Company, in charge of the waterworks, electric light plant and mill construction and operation. Since leaving the Sault I have been principal assistant engineer of the Sanitary District of Chicago. (See Vol. 7, p. 7008.)

Professor George Dock,

Called as a witness by the defendants, qualified as follows:

I am a physician and teacher of medicine, and have a chair of theory and practice of medicine in the University of Michigan. I have been there for thirteen years. I was educated in Harrisburg, Pennsylvania, and graduated in medicine at the University of Pennsylvania in the year 1884. The next year I

spent in a hospital in Philadelphia, St. Mary's Hospital, in the worst typhoid fever district of Philadelphia, in Kensington, Philadelphia, where I saw a good deal of typhoid fever, and I spent a year at that. I was interne at that hospital, and had charge of various classes of patients, and part of the time I was in the dispensary, where I had to examine a great many patients and go out and see a great many patients in houses.

After that I went to Germany to prosecute my studies in medicine, internal medicine especially. I went to Leipsic at that time, which was very full of typhoid fever. My experience in Philadelphia, where I was expecting to settle, had increased my interest in the disease, and I paid a great deal of attention to typhoid there. That was before they had improved the water supply and sewage of Leipsic, and there was a great deal there. I spent part of the year there, then I went to Berlin and saw a great deal of typhoid fever there. I studied the bacteriology of it in both those places, and spent altogether two years over there in the study of pathology and internal medicine. I studied at the Universities of Leipsic, Berlin, Vienna, and in the Pathological Institute in Frankfort.

Then, after getting through there, I went back to Philadelphia, where I was assistant to Doctor Osler, and Doctor Musser, in the University Hospital. I also had charge of the part of the Medical Dispensary in the University of Pennsylvania, and practiced there, too. I saw a great many cases of typhoid fever, and there I began the study of malaria. Dr. Osler was then the first man in America, studying malaria. He had a great many cases brought in to him from the outside. I spent a great deal of time working on them and became very much interested in the practical diagnosis of malarial diseases.

Doctor Osler is now professor of medicine at the Johns Hopkins Hospital.

Then, after that, I had an offer to go down to Galveston, Texas, to teach medicine and pathology. I went there chiefly on account of my interest in malaria. I went down there and stayed there three years. I was professor of pathology in the

Galveston Medical School and physician to the hospital connected with the medical school, and the last two years I was there practiced. In Galveston I found they were diagnosing practically no typhoid fever at all, and yet I saw lots of typhoid fever patients there. I was able to see that cases that were diagnosed as malaria and typho-malaria were typhoid fever, and my experience showed me that none of these cases had malaria. I did, however, see fatal cases of malaria. They were all cases that either came from the tropics, Nicaragua or Panama, or else came from the interior of Texas, where they occasionally have very severe forms of malaria. I became very much interested in the practical diagnosis of so-called malarial diseases, continued malaria, and various local names that are given to this disease, and did some work on it, wrote an article, read a good many papers on the subject before medical societies.

On one occasion I made an offer to visit any patient having typho-malaria, or continued malaria, and examine the blood free, in order to settle whether it was malarial fever or could be diagnosed as typhoid. I never had occasion to have my offer accepted. In Texas I studied the characteristics of malarial fever as they obtained in the southwestern part of the country. I saw many cases and examined them all very carefully and thoroughly, wrote several papers on the subject that have been widely quoted, and became looked upon as somewwhat of an expert in malarial diseases.

After leaving Galveston I went to Ann Arbor, and there I had the same experience I had in the South. I found that the doctors were diagnosing many cases of typho-malarial fever. My int rest, of course, was still alive. I examined many of those cases, *post mortem* as well as in life, and I was able to show the same thing, cases that were diagnosed as typho-malarial and continued malarial were all cases of typhoid fever. In Michigan I did not see any fatal cases of malaria at all. Since then I have examined a great many cases every year. I have cases sent in under the diagnosis of typho-malaria or some similar name and I have frequent occasion to clear up the diagnosis.

I have acquainted myself with the characteristics of malarial fever as they occur in the Mississippi Valley.

I have given attention to the questions of malaria in St. Louis, and the literature bearing upon malaria there.

I was asked by Surgeon General Sternberg, of the United States Army, in 1898, to visit certain army camps in order to examine the blood of patients diagnosed largely as malaria. In accordance with that, I examined the Sternberg general hospital at Chickamauga, the hospital at Knoxville, and at Camp Meade, Pennsylvania. At that time most of the cases of typhoid in the army camps were diagnosed malaria. In the Sternberg hospital, for example, there were 400 patients when I got there, and practically all of them had a diagnosis of malaria, in one form or another, typho-malaria, bilious, remittent, or some such name. I examined most of these patients individually. I examined their blood and examined their clinical features, with the result that I found only one case out of the whole 400 had malarial fever. (See Vol. 8, page 7044.)

Lewellys F. Barker,

Called as a witness by the defendants, qualified as follows:

I reside at Chicago, Illinois. I am a professor in the University of Chicago. I have been a professor in the University of Chicago for a little more than three years. I am professor in the medical faculty, temporarily in charge of the department of anatomy, pending the establishment of a research department of internal medicine. I was nine years associated with the medical faculty of the Johns Hopkins University at Baltimore, Maryland. During my first year I was assistant to Professor William Osler, of the department of internal medicine; then for two years I was fellow in pathology and bacteriology with Professor W. H. Welch, and then I was appointed to an associateship in anatomy with Professor Mall, then to assistant professorship in anatomy, and during my last period in Baltimore I was made associate professor of pathology with Doctor Welch, of Johns Hopkins.

Prior to my connection with Johns Hopkins University I was a year as interne or house physician and surgeon in the Toronto General Hospital, immediately after my graduation in medicine.

After graduating in Toronto I went for one year in this hospital in Toronto as the acting house physician and surgeon, then I went immediately to Johns Hopkins and was there for nine years, and then came to Chicago; but I was away from Baltimore at various periods, studying in Germany and on various commissions. In Germany I spent most of my time at the University of Leipsic. I visited other schools, but did no special work in other places. I have been on various commissions. The first commission was one established by the State Board of Health of Maryland. Doctor Flexner and I were sent to the Loona County Valley to study an epidemic of a peculiar disease the diagnosis of which seemed uncertain, but which turned out to be epidemic cerebral spinal meningitis. In 1899 the Johns Hopkins University sent Doctor Flexner and myself as special commissioners to study the tropical diseases in the Philippine Islands, and incidentally to study the epidemics of plague and beri beri in Hong Kong, India and Japan. We were six months on that commission.

In Japan we were fortunate enough to visit Gute's laboratory and meet there Shiga, who worked out the bacillus of acute dysentery in Japan. That proved to be a very important visit for us, for later in Manila we were able to isolate some of the cases of dysentery in those islands, with apparently the same bacillus as Shiga had isolated in Japan.

The first year I came to Chicago I was appointed by the Secretary of the Treasury in Washington, along with Professor Flexner, of the University of Pennsylvania, and Professor Novy, of the University of Michigan, to proceed to San Francisco and investigate the disease prevalent there among the Chinese, and to ascertain whether or not it was bubonic plague.

Have made a special study of typhoid fever and malarial fever. (Vol. 8, p. 7082.)

Professor Theobald Smith,

A witness called on behalf of the defendants, qualified as follows:

I am professor in the Harvard Medical School and pathologist of the State Board of Health of Massachusetts. I have been connected with the State Board of Health of Massachusetts since 1895. Prior to that I was bacteriologist and in charge of the investigations in the Department of Agriculture at Washington upon infectious diseases of animals. At the same time I was professor of bacteriology in the Columbian University medical department at Washington, District of Columbia. I am a graduate of Cornell University and Albany Medical College. I graduated from Cornell University in 1881. After graduating from Cornell University I spent two years in the study of medicine at the Albany Medical College. After that I spent about six months in special work at Cornell, then I went to Washington, in the fall of 1883. My work in Washington was chiefly the study of infectious diseases of animals in the agricultural, and professor of bacteriology in the medical department of Columbian University. I was engaged in that work there until 1895. Since the year 1895 I have been professor in the Harvard Medical School and pathologist of the State Board of Health of Massachusetts.

I began to be interested in the bacteriology of water in 1886, when I made observations upon the bacteriology of the Potomac River water. That was at a time when we simply determined the total number of bacteria. In 1891 I was engaged for a number of months on a sanitary survey of the Hudson River between Schenectady and Albany in view of the pollution of the river there and the prevalence of typhoid in Albany and New York. Last year I was engaged in looking over the bacteriology and the general sanitary status of the Charles River basin around Boston with reference to the building of a fresh water basin. I have given the question of typhoid fever consideration, because that is the main question involved in our

climate, the bearing of drinking water upon typhoid and other intestinal infections.

The scope of the Massachusetts Board of Health is to take charge of the water supply of the whole State and its business is to examine into the relative purity of waters in the State, and also determine the best methods of sewage disposal.

I have given the subject of bacteriology, as applied to water and pathogenic bacteria, considerable attention. I have published about sixty or seventy papers on the subject of bacteriology, not exclusively in relation to drinking water, but in relation to diseases generally. I have studied practically all the pathogenic bacteria that are accessible except the plague bacillus.

I devised a method to differentiate between the colon bacillus and the typhoid bacillus. (See Vol. 8, p. 7288.)

Professor Victor C. Vaughan,

A witness called by the defendants, qualified as follows:

I am a physician and a teacher. I live in Ann Arbor, Michigan. I am connected with the University of Michigan. I took a master's degree there in 1875, doctor of philospohy in 1876 and doctor of medicine in 1878.

After graduating from the University of Michigan in 1878, I taught in the University of Michigan and practiced medicine. I have also studied abroad to some extent. I studied with Robert Koch in the University of Berlin. I have been there two or three times. The longest time I was there was for about three months, in 1888. I teach hygiene and physiological chemistry. I have made a study of the so-called germ diseases. As a teacher of hygiene it would be necessary for me to study the germ diseases.

I have been a member of the Michigan State Board of Health. I am serving my third term now as a member of that board. I have been called upon frequently to examine into epidemics in the State and I served on the Government commission

and am still serving on the United States Government commission for the study of typhoid fever.

I enlisted in the army June 9, 1898, and I think the special commission appointed to study typhoid fever was some time in August, 1898. In August, 1898, after my return from Santiago, there was a commission appointed to investigate the causes and spread of typhoid fever in the camps of the United States. This commission consisted of the late Major Walter Reed, the late Major Shakespeare and myself, and we inspected the camps.

We went to Camps Alger, Fernandino, Jacksonville, Huntsville, Alabama; Chickamauga, Georgia; Knoxville, Tennessee; Camp Meade, Pennsylvania; and the other members of the commission went to Montauk. I did not. I was sick at the time. I think several thousand cases of typhoid fever, four or five thousand probably, came under my observation.

As a member of the commission I have been engaged practically ever since that time in writing up the statistics and studying the spread of typhoid fever, and I have also been called upon frequently to investigate outbreaks of typhoid fever in different parts of the country, in Michigan and other States as well.

I have made a special study of typhoid fever and malarial diseases. (Vol. 8, p. 7313.)

Professor Leonard P. Kinnicutt.

A witness called by the defendants, qualified as follows:

I am the director of the chemical department of the Worcester Polytechnic Institute, located in Worcester, Massachusetts.

I graduated at the Massachusetts Institute of Technology in 1875 with the degree of bachelor of science. I studied in the University of Heidelberg for two years under the direction of Professor Bunsen. I then studied two years at the University of Bonn, Germany, in the laboratory of Professor Kekule. I then studied for four months at Johns Hopkins University, then at Harvard University, where I obtained the degree of doctor of science.

Since graduation, or since receiving my degree of doctor of science, I was instructor in chemistry in Harvard University for three years. I was then appointed assistant in chemistry at the Worcester Polytechnic Institute. After three years I was appointed full professor of chemistry and then director of department of chemistry in the Worcester Polytechnic Institute, which office I now hold.

I have been consulting chemist to the Worcester Board of Health since 1885. I was the consulting chemist to the Connecticut Sewage Commission, appointed by the Legislature. I have been for fifteen years fellow of the American Association for the Advancement of Science, of which I am now one of the vice-presidents. Member American, English and German Chemical Societies, member of the American Bacteriological Society, etc.

I have made a special study of sanitary problems, beginning in the year 1882, which study I have continued from that time.

I have made a special study of the analysis of water, both chemical and bacterial analysis of water, and I am continually employed in making such determinations. I have had experience in the interpretation of bacterial and chemical analysis of water, as all water analyses require the interpretation of both chemical and bacterial results.

I have had experience in passing upon the water supply of numerous cities, among which I can name Gardner, Massachusetts; Quincy, Massachusetts; Bristol, Rhode Island; Warren, Rhode Island, and various other towns and cities in the East.

I have made a special study of bacteriology as applied to water investigations, as such study is necessary for determining the character of a water.

I have made a study of the typhoid bacillus as related to water supplies of the coli bacilli, and also the typhoid fever death rates of cities whose waters I have examined.

I have studied the colon bacillus in the determination of the character of water supplies, as that is one of the most important single determinations that we make.

The typhoid bacillus is very closely related to the colon ba-

cillus, both belonging to the colon group, and can only be distinguished from each other by special tests.

I am acquainted with the physical conditions of the Chicago River, the Drainage Canal, the Desplaines and the Illinois Rivers, and the Mississippi River, from Chicago to St. Louis.

I have made a special study of the problem of sewage disposals, both in the United States and in England. My investigation on the sewage disposal problem began in 1882, when I was asked to give my advice to the city of Worcester regarding the disposal of the city sewage. Since that time I have devoted a great deal of my attention to the subject of disposal of sewage. I have conducted experiments of my own lasting through periods of over two years on the question of purification of sewage by the septic tank, having a tank in continuous operation, holding over 1,500 gallons. I have visited all the sewage purification plants in Massachusetts, and have visited most of those in England.

I studied the disposal of the London sewage by chemical precipitation. I have studied the system of septic tank treatment and contact bed treatment as carried on at Manchester. I have studied the system of chemical treatment and land irrigation as carried on at Birmingham.

I visited, the first year it was put in operation, the first septic tank in England at Exeter, and carefully studied its operation.

Since 1896 I have visited England every other year, studying what was being done in England regarding the methods of treatment of sewage.

I have conducted an experimental septic tank, which I have already stated contained 1,500 gallons, making very careful experiments continuously for two years. I have also conducted experiments on a practical scale, in a large open septic tank holding 250,000 gallons, analyzing the sewage, the effluent, the gas that was given off, and studying the processes that took place in the septic tank. (Vol. 8, page 7336.)

Professor William S. Thayer,

Called as a witness by the defendants, qualified as follows:

I am a physician, residing at 406 Cathedral Street, Baltimore. I graduated at Harvard University, in the academic department, in 1885, and in medicine in 1889. I spent a year as house physician at the Massachusetts General Hospital. After that I spent a year abroad in studying, in Berlin and Vienna, and in the fall of 1890 I came to Baltimore as assistant resident physician in the Johns Hopkins Hospital. In the fall of 1891 I was appointed resident physician. In the fall of 1895 I was made associate in medicine at Johns Hopkins University, and in 1896 or 1897 associate professor of medicine, which I have been since then. I lived in the hospital as resident physician from 1891 to 1898. I studied in Paris for three months during the fall of 1893. I am one of the physicians in chief of the Johns Hopkins Hospital dispensary, associate in medicine at the Johns Hopkins Hospital, associate professor of medicine in the Johns Hopkins University, and visiting physician to the Union Protestant Infirmary.

I have made a special study of the so-called germ diseases, and malarial fever, and typhoid fever particularly. (Vol. 8, p. 7465.)

Mr. John W. Hill,

Called as a witness by the defendants, qualified as follows:

I am an hydraulic engineer. At the present time I am employed by the city of Philadelphia as chief engineer of the bureau of filtration, a bureau that has been conducting the general improvement of the water supply of that city by filtration of the Delaware and Schuylkill waters, which now and hereafter will form the sources of public water supply for Philadelphia, and partly by reducing the consumption of water from the Schuylkill River and increasing the consumption of water from the Delaware River.

The extent of the work embraces, as a first proposition, the filtration of 320,000,000 gallons of water per day of twenty-four

hours, the transfer of the chief source of supply from the Schuylkill to the Delaware River, and a general reorganization of the distribution system brought about by reason of the principal volume of water in the future coming from the Delaware instead of the Schuylkill River. It will involve a cost of about $26,000,000. Of that amount about $17,000,000 worth of work has been accomplished at the present time. Part of the system of filtration is now in daily operation and has been for a period of twenty months.

At the time when I first engaged in the planning and building of works of public water supply, I should say about thirty-two years ago, I first began the study of sanitary problems. From that time up to the present date information touching the hygienic quality of water supply has always been interesting and, as a rule, an essential part of my work.

I have been associated with about sixty works of public water supply, including different questions looking either to the general construction or improvement of municipal water works. Wherever my engineering association with public water supply has touched the question of a water quality, investigations have been made to determine the desirability of available sources.

Prior to coming to Philadelphia, four years ago, my principal work along this line was in behalf of the city of Cincinnati where I was chairman of the original board of engineers that made an investigation and furnished the plans upon which the present improvements at that point are being constructed. As a part of the Cincinnati work and for other cities for which I have done engineering along the Ohio River, investigations have been made at Parkersburg, Madison and Jeffersonville, Indiana, to determine the advisability of drawing water from the Ohio River for drinking and other domestic uses. The same investigations have been made in behalf of the city of Clarksburg, West Virginia, and in behalf of many smaller cities on streams in the States of Ohio, Indiana, Michigan and Illinois, which were to be drawn upon as sources of public water supply. Mention

ing some of these cities where streams have been discussed as sources of water supply are:

Findlay, Ohio; Greensville, Ohio; Eaton, Ohio; Marion, Ohio; Zanesville, Ohio; Bellefontaine, Ohio; Huntington, Indiana; Lebanon, Indiana; Greenville, Indiana; Indianapolis, Indiana; Aurora, Indiana; Decatur, Illinois; Peoria, Illinois; Oshkosh, Wisconsin; East Saginaw, Michigan; Buffalo, New York; Saratoga Springs, New York; Chester, Pennsylvania; Nashville, Tennessee; Chattanooga, Tennessee; Birmingham, Alabama; Mobile, Alabama; Denver, Colorado; Trinidad, Colorado; Pueblo, Colorado.

All of the cities mentioned have submitted either in the course of my work as engineer, planning new works or improvements of old works, questions including the availability of different or single sources of water supplies. I say single source especially with reference to towns along the Ohio River where it is rare that any other source can be had than that of the main stream.

Aside from purely engineering investigations of watersheds where rivers or ponds have been the sources of public water supply, I have taken up the subject of bacteriology and attempted to qualify myself as an amateur in this line, not with a view to pursuing bacteriology as a profession, but with a view to gain information as to the bacteriological condition of water supplies with which, as an engineer, I would be required to deal. Such work was pursued during leisure time, uninterruptedly from 1894 to 1899. It has been interrupted since coming to Philadelphia, because of lack of time to indulge in the experimental or technical work.

I have also studied the chemistry of water supplies, not with a view to chemical analysis, but with a view of informing myself as to the true interpretation of chemical analysis of water samples, in connection with my work as engineer in charge of the improvement of the water supply of Philadelphia.

I have investigated typhoid epidemics. Two that I now recall, one at Eaton, Ohio, and one in the Cumberland Mountain

regions of Kentucky. Both as a part, however, of investigations looking to the improvement of the water supply for the city of Cincinnati. In addition to the investigations noted, I have sought information where it has been obtainable in the English or German publications of epidemics that have been reported on in the United States and Europe.

I have had experience in the interpretation of chemical analyses of water. It has gone through the whole period of thirty-odd years. The first set of analyses that I can recall from memory were made for the city of Sidney, Ohio, by Professor Chauncey R. Stuntz, analytical chemist of Cincinnati, as early as 1872 or 1873. Of course, it must be understood that the sanitary analyses made thirty years ago are not the same as those made to-day.

It is a part of my duty to pass upon the technical investigation of our water supplies coming to and from our filters and from them to determine the efficiency of our work of filtration; to do this it is necessary to assign proper values to the results reported from day to day from the technical laboratory.

I have made a special study of bacteriology as applied to water investigations. (See Vol. 8, p. 7502.)

III.

CHEMICAL AND BACTERIAL SURVEYS.

Prior to the opening of the Drainage Canal the defendants entered upon the most elaborate and complete chemical and bacterial survey of the waters between Chicago and St. Louis that has ever been attempted. The Sanitary District, in conjunction with the Illinois State Board of Health, entered upon this work in the early part of 1899, for the purpose of ascertaining the conditions existing in the waters of Lake Michigan, the Illinois and Michigan Canal, the Desplaines River, the Illinois River and its tributaries, the Mississippi River above Grafton, the Missouri River above its mouth, and the Mississippi River at the Chain of Rocks.

So comprehensive was this undertaking that the laboratories of the city of Chicago, of the University of Chicago and the University of Illinois were selected as the proper places, on the part of the Sanitary District, for making these analyses. These surveys were made jointly at these different laboratories. Dr. Gehrmann and Mr. Bisbee, who had charge of the laboratory of the City of Chicago, and Professor E. O. Jordan, of the University of Chicago, and Professors Burrill and Palmer, of the University of Illinois, were selected by the Sanitary District to analyze the samples of water collected from the different streams covering this period.

This investigation on the part of the Sanitary District covered three periods of time. One extending from April, 1899, to the end of the year; the second period extending from the 1st of January, 1900, to the end of June, 1900, and the third period from October, 1901, to about the 1st of January, 1902.

The waters selected to be analyzed were taken from the Illinois and Michigan Canal, the Illinois River, the Desplaines River, the Kankakee River, Fox River, Big Vermilion, Sangamon River, Mississippi and Missouri Rivers, and Lake Michigan.

The samples for 1899 and 1900 were taken at the following points:

From the Illinois and Michigan Canal at Bridgeport, a little below the pumping station. From the Illinois and Michigan Canal at Lockport, and also from the Desplaines River at this point.

During the second period samples were taken as well from the Drainage Canal near its union with the Chicago River, and also from the Drainage Canal at Lockport, near the Bear Trap Dam.

At Joliet two samples were taken, one from above the town and one from below.

At Morris, on the Illinois River, one sample was taken.

At Ottawa a sample was taken from the Illinois River above the town, and a sample was taken from the Fox River above its mouth.

At La Salle a sample was taken from the Illinois River, one from the Big Vermilion River, and one from the Illinois and Michigan Canal at this point.

The next sample was taken from Henry, in the Illinois River.

The next sample was taken from the Illinois River at Averyville, above Peoria, near the city waterworks.

A sample was taken from below Peoria, at Wesley City.

One from the Illinois River at Pekin; one from the Illinois River at Havana; one from the Sangamon River at Chandlerville; one from the Illinois River at Beardstown; one from the Illinois River at Kampsville; one from the Illinois River at Grafton, and one from the Mississippi River at Grafton. At Alton, Illinois, below the mouth of the Illinois River, a series of five samples were taken from the Mississippi River, at equally distant points across the Mississippi.

A sample was taken from the Missouri River at West Alton, near its mouth. At the Chain of Rocks, where the intake tower of the St. Louis waterworks is located, four samples were taken across the river, as at Alton.

A sample was also taken of the St. Louis water supply, as drawn from a tap in the city of St. Louis.

In addition to these, a sample of Lake Michigan water was

examined at more or less regular intervals throughout this period, the samples being drawn from the laboratory tap. Samples were taken approximately at weekly intervals, on several occasions.

The third period of this investigation, sample was taken by agreement with the authorities of the city of St. Louis, at certain designated points. These points were at Peoria, from a short distance above and below the city; at Grafton, at the mouth of the Illinois River, samples being taken from both the Illinois and the Mississippi at this point, and at the Chain of Rocks, the source of the water supply of St. Louis, where samples were taken across the stream as in the preceding examinations.

Samples were also made from the Missouri River at Fort Bellefontaine.

During the last examination analyses were made in laboratories which were established under the direction of Professor Jordan, at Peoria, at Grafton, and at St. Louis.

In selecting the places to take these samples, a conference was held between the scientists who were to make the analyses.

Professor Jordan, on page 5810 of the printed record, describes the manner of selecting the points, as follows:

"At a conference between Professor Palmer, Doctor Gehrmann, Doctor Reynolds, Mr. Randolph, Doctor Reilly and myself, in the office of the Health Commissioner of Chicago, the field was gone over in some detail, and certain points indicated as being favorable points for collection, in the opinion of the gentlemen attending this conference. In consequence of this conference, Professor Palmer and I were appointed to visit the places indicated, and to determine whether, in our opinion, these were the most suitable points for the collection of water samples, and whether if, that being so, it was possible to make satisfactory arrangements with reliable persons for the collection of such samples at stated intervals.

"In March, 1899, we visited most of the points that I have mentioned as being the places from which samples of water

were actually collected. In each case we made a special effort to obtain the services of some person whom we supposed to be trustworthy, for the purposes of collecting water samples. These persons were provisionally engaged by us through a personal interview for this purpose."

After the places had been selected and men had been chosen to collect these samples, written instructions were given for the collecting and sending of samples of water for analyses, which written instructions are as follows:

"The outfit for obtaining water samples consists of two parts. The large gallon bottle is for the chemical sample and the small, four-ounce bottle is for the bacterial sample. The large and the small bottle together constitute one sample or set. The two bottles must be filled at the same time and in the same place, and in the same general manner. They must then be placed in their respective compartments of shipping cases, for transportation. In filling the bottles, the stoppers should be taken out only when the spot from which the water is to be taken is reached. The bottle is immersed with the stopper in place about one foot below the surface, and a small quantity of water allowed to run in. This is shaken and emptied. The bottle is then reimmersed with the stopper in place and is filled, leaving about one or two inches air space. The large and small bottles are then immediately sealed by placing the rubber cloth over the stopper, and drawing the wire seal with the number for the sample tight around the neck. The small bottle is to be placed in the smaller can, and the lid pressed down. It is then to be packed in ice, within the large can. The card in the shipping envelope is then to be filled out and attached to the neck of the larger bottle. The bottles should not be filled until just before the time for delivery at the express office. As series of samples are to be sent to different laboratories, all of the bottles should be filled at the same time and at the same place, and the different sets placed together as described."

These instructions were printed upon cards, and on the reverse side of the card were the following:

"Streams examination, Chicago, Sanitary District, Sample of water. Fill this out and place in shipping envelope. Fasten to larger bottle by end of wire seal. Sample No. —— date and time —— from —— collected by. Height of water, direction of wind, temperature of water, temperature of air, and a note as to the absence or occurrence of rain since the last sample was taken, as well as remarks upon the passing of vessels, changes in current and so on.

"These items were filled out by the collector on the several cards. They were enclosed in an envelope, sealed and addressed to the three laboratories that took part in this work, and the samples with the attached cards were shipped; one set to the University of Illinois, one set to the municipal laboratory in Chicago, and one set to the University of Chicago."

This was the method employed by the Sanitary District in making the chemical and bacterial survey on the water course between Chicago and St. Louis, and demonstrates the thoroughness that was employed in carrying on this investigation.

For the State of Illinois, Professor John H. Long made an independent chemical survey for the period 1899, 1900 and 1901. The places selected by Professor Long were Bridgeport, at the source of the Illinois and Michigan Canal, within the city of Chicago, located near the corner of Ashland Avenue and Thirty-first Street. Also the Illinois and Michigan Canal at Lockport, 200 feet east of the main bridge. Samples were taken from the Desplaines River at Lockport, the location being above the stone bridge north of the town. Also Joliet, Morris, Ottawa, La Salle, Henry, immediately above the city of Peoria, known as the Peoria Narrows, and sometimes described as Averyville. Also Peoria, or Wesley City, Pekin, Havana, Pearl, Grafton, at the mouth of the Illinois River. Also from the tributaries of the Illinois, the Kankakee, near the town of Wilmington, Fox River, Big Vermilion River, Spoon River, Sangamon River, the Mississippi River at Grafton, above where the Illinois River enters.

Also samples of water were collected from the headwaters

of several of the tributaries, such as the Kankakee River, near South Bend, Indiana, the upper Desplaines at Libertyville, the upper Du Page near Wheaton, the upper Fox River at McHenry, the upper waters of the Big Vermilion River at Pontiac, from the Mackinac River at the town of Capper, also from the upper Sangamon River at Mahomet, and from the upper Spoon River at Dahinda. (4108.)

In Professor Long's 1901 investigation samples were taken from the mouth of the Missouri River, at a point 200 yards above its junction with the Mississippi; the Mississippi River above Grafton, and the Illinois River above Grafton.

The collectors were all selected by Professor Long personally, and instructed as to the method of collecting the samples, as to the places where the samples should be taken, and as to the method of forwarding the samples to his address in Chicago.

In this series of investigations two samples of water were taken at each point. First a large sample of about a gallon was taken in a so-called gallon bottle, this sample being used for the chemical analysis. The second smaller sample, of about six ounces, was collected in a small bottle, this water to be used for the so-called bacterial examination. (4111.)

These samples were to be shipped by the express companies to Chicago. They were delivered by the companies, and received either by himself personally or by his assistants.

Professor Zeit, of the Northwestern University, had charge of the bacterial examination for the State of Illinois, and analyzed the bacterial sample for the State of Illinois.

It will be observed that in carrying out this joint investigation by the Sanitary District of Chicago and the State of Illinois upon the water courses above described, that it is the most comprehensive and complete chemical and bacterial survey that has ever been made of any stream, either in this country or in Europe. The results of this investigation, together with the analytical tables, both chemical and bacterial, are set out in full in the printed testimony of this case, in the testimony of each of the witnesses who were selected to perform this work.

In addition to the joint chemical and bacterial survey conducted by the Sanitary District in the manner as heretofore detailed, and the State of Illinois under the supervision of Professor John H. Long, as also set out,—the evidence of Professor Palmer discloses the fact that for a great many years prior to the opening of the Drainage Canal he had been steadily engaged in making chemical analyses of the waters of the Illinois River and its tributaries, under the direction of the Illinois State University.

Professor Palmer in his testimony (5306) states:

"I began the investigation of the water supplies of Illinois in 1889; but did not begin a systematic investigation of the Illinois River until the summer of 1894."

By an act of the State Legislature of Illinois approved June 7, 1897, and in force July 1, 1897, it was enacted that the trustees of the University of Illinois are hereby authorized and directed to establish a chemical and biological survey of the waters of the State, in connection with said university, to collect facts and data concerning the water supplies of the State; to collect samples of waters of streams and to subject such samples to chemical and biological examination and analysis as shall serve to demonstrate their sanitary condition, and to determine standards of purity of drinking waters for the various sections of the State; and to publish the results of these investigations in a series of reports to be issued annually or oftener, to the end that the conditions of the potable waters of the State may be better known, and that the welfare of the people of the various communities of the State may thereby be conserved.

It was a part of the duty of Professor Palmer, as head of the department of chemistry of the University of Illinois, and in charge of the surveys of the waters of the State of Illinois, to make a chemical survey of the waters of the Illinois River.

The evidence of Professor Palmer discloses the fact that surveys of the Illinois River were introduced in evidence from 1894 to 1901. (5306.)

Professor John H. Long, in addition to the chemical surveys

of the waters of the Illinois River as heretofore detailed, began as far back as 1885, to make analyses of the Chicago River, Lake Michigan, and the Illinois and Michigan Canal; and, in 1886, he made a study of the water samples taken weekly at a number of points, beginning at Bridgeport and continuing down the river to Peoria; at points located at Lockport, Joliet, Ottawa and La Salle; and subsequent to that, in a second series of experiments, in the winter of 1886 and 1887, between January and December, covering a period of two or three months, at the same points selected as in 1886; and two years later, beginning in the summer of 1888, continuing into the fall and ending in the middle of November, 650 chemical examinations were made at the same points as heretofore selected and continuing below Peoria to the mouth of the Illinois River at Grafton. (3997.)

Also an investigation was made by him in 1888 and 1889, as well as in 1890 and 1891. The purpose of all these analyses was to show the effect of the discharge of the sewage from Chicago on the Illinois River. (4001.)

It will be plainly seen, by a consideration of the foregoing chemical surveys of the Illinois River and its tributaries, made by Professors Long and Palmer prior to the joint investigation made by the Sanitary District and the State of Illinois in 1899, 1900 and 1901, that no river in this country has been so carefully and so thoroughly investigated for such a period of time by scientific men as has been the Illinois River and its tributary streams, as the same is disclosed by the evidence in this case; and defendants assert that the records in this case of the work done by chemical and bacterial experts who have testified in behalf of the defendants, and have displayed the result of their labors in the testimony that each has given in this case,—demonstrate, beyond any question, the ability, integrity and competency of the men selected by the Sanitary District and the State of Illinois to make these chemical and bacterial surveys for the periods 1899, 1900 and 1901.

In order to appreciate the nature and weight of the evidence

derived from the chemical and bacterial examinations of river water, it is necessary to consider certain technical features relating to these analyses and their interpretation.

Interpretation of Chemical Data.

In examining the water by chemical methods to determine its wholesomeness, in making what is termed a sanitary analysis of the water, certain facts and principles universally recognized by sanitarians must be taken into consideration. It is true, in the first place, that the chemist in analyzing a water for its potability does not test directly for harmful substances. The chemical constituents upon which the chemist and sanitarian rely for basing their judgment as to the character of a water are not in themselves harmful in the amounts in which they occur in natural waters. The amount and nature of these constituents simply furnish evidence more or less cogent as to the sanitary history of the water. The most significant determinations for establishing the sanitary character of waters are as follows:

1. *Chlorine.* This element is contained in water chiefly in the form of common salt. It is present in greater or less abundance in all waters, streams, ponds, lakes, wells, etc. Salt is contained in kitchen waste, in the waste products of many manufacturing processes, in certain animal secretions and exudations, especially urine, and chlorine is, therefore, always found in sewage and sewage polluted waters in larger quantity than in pure or virgin waters. When it enters a stream it does not undergo any decomposition or change, and the only natural causes of change in the proportion of chlorine in the water are through evaporation of the water by the sun's heat, by the addition of water containing larger amounts of chlorine, by dilution with water containing less chlorine than the water in the stream, or perhaps to some small extent by the abstraction of the chlorine by plants and animals living in the water. Owing to the permanence of the salt, the amount of chlorine in the polluted water affords no indication as to whether pollution is recent or

remote. The amount of chlorine in the Illinois River at its mouth would be the same whether twenty days or two thousand days were consumed in the passage of the contents of the Drainage Canal from Lockport to Grafton, assuming evaporation, dilution, supplementary pollution and the like to remain the same. In other words, in following the passage of salt down stream in a polluted river, valuable information is obtained concerning the degree of dilution and mixing, but, on the other hand, no clue is afforded to the rapidity and extent with which processes of oxidation and bacterial purification are taking place. (Page 7351.)

2. *Oxygen Consumed.* By oxygen consumed is meant the amount of oxygen necessary for the destruction or oxidation of substances contained in the water. This determination serves as an index to the amount of carbonaceous matter in the water. Other things being equal, polluted waters contain more oxidizable matter than pure waters, and hence the amount of oxygen consumed gives some indication as to the amount of organic matter present in the water. (Page 7353.)

3. *The Nitrogenous Compounds.* The most significant compounds in a polluted water are those of a nitrogenous character. These nitrogenous compounds are usually determined in four different states, as albuminoid ammonia or organic nitrogen, as free ammonia, as nitrites and as nitrates.

(a) *Albuminoid Ammonia.* The amount of substance under the head of albuminoid ammonia or organic nitrogen indicates the amount of decomposible nitrogenous substance like albumen or proteids in a water. The dead bodies of plants and animals and the excreta from living organisms furnish the nitrogenous compounds that are included under this heading. It is claimed that not only the undecomposed matters in fresh sewage may yield albuminoid ammonia to the analyst, but also vegetable matters such as dead leaves, grasses, algae and the like.

"From any methods of chemical analyses known, it is impossible to tell whether the substance represented by the term

albuminoid ammonia is derived from animal or vegetable matter." (Whipple, 2063.)

There is, hence, no way known to chemistry of distinguishing between the albuminoid ammonia derived from fecal matter introduced in sewage and that derived from dead leaves, algae, etc., in the water. The significance of Professor Kinnicutt's statement (7352) that something "regarding the character of the water must be known before a perfectly correct idea of the significance of albuminoid ammonia is arrived at" is therefore evident. The albuminoid ammonia or organic nitrogen reported by the various analysts for complainant and defendants as being present in the water of the Illinois River at its mouth may, therefore, so far as the chemist can determine, be derived either from drainage recently added to the river or from the bodies of dead fish and other aquatic animals or from the swarming myriads of microscopic plants and animals in this stream, or from the decomposing vegetable matters which are present in such great abundance in the overflowed bottom lands of the Illinois River.

(b) *Free Ammonia.* Free ammonia represents the first stages in the decomposition of the organic nitrogenous bodies. In fresh sewage it is often contained in comparatively large quantities, and occurs in still larger quantities in sewage in which the first stages of putrefaction are taking place; that is, the alteration or decomposition of the organic nitrogen into saline ammoniacal compounds. Free ammonia may also arise from the death and decomposition of microscopic animals and plants living in the water. In general it may be said that a fresh sewage contains a relatively large proportion of nitrogen in the form of albuminoid ammonia, while a stale sewage contains a small proportion of nitrogen in the form of albuminoid ammonia, bacterial activity having converted the albuminoid ammonia into free ammonia. (5954.) Free ammonia in a water, therefore, sometimes represents the early stages of decomposition of organic matter introduced into such water, and under these conditions may indicate the recency and amount of

pollution. It may, however, originate just as abundantly from decomposing organic matters of vegetable origin. For example, the free ammonia in the Illinois River at its mouth may come, and at certain times of the year does come, largely if not wholly from the death of microscopic algae in the water, which die and decompose at the approach of cold weather and under other adverse conditions. (7352.)

(c) *Nitrites.* Nitrogen in the form of free ammonia in a water is not a stable compound, but can be oxidized by bacterial activity into nitrites. The presence of nitrites in a water, therefore, indicates that the free ammonia is being oxidized. And in general the occurrence of nitrites in a water is taken by the sanitarian to mean that the processes of decomposition are actively taking place. Nitrites may also arise by the reduction of nitrates. This occurs when organic matter is added to a water containing nitrates; the process of reduction being due to the activity of bacteria, which, to satisfy their need of oxygen, rob the nitrate of oxygen, reducting it to nitrite. The interpretation to be given to the amount of nitrite in the water, therefore, is widely different under different conditions. It may represent the oxidation of ammonia or the reduction of nitrate. If, for example, the algae in a water rich in nitrate begin to die at the onset of cold weather, the organic matters in their bodies furnish food for bacteria, which reduce the nitrate in the water to nitrite. In such a case the presence of nitrite in the water would have no sanitary significance. (5954-5.)

(d) *Nitrates.* Certain kinds of bacteria, furthermore, are able to oxidize nitrites to nitrates in the absence of organic matter. Nitrates, therefore, indicate the fully oxidized condition of the nitrogenous matter introduced in sewage and are the last stage in the removal or oxidation of organic matter in a stream. A water may be from a sanitary standpoint perfectly wholesome and yet contain a large amount of nitrates. In this respect the meaning attached by sanitarians to the presence of nitrates is exactly similar to that attached by them to the pres-

ence of chlorine. Nitrates and chlorine in a water, taken by themselves, throw light on the past history of a water, but afford no ground for passing judgment upon the condition of the water at the time of its analysis. (7353-7354.)

Summing up the changes that take place in the nitrogenous matter introduced into a stream by sewage, it is seen that the complex organic bodies originally introduced give rise to free ammonia, which is oxidized more slowly to nitrites, and these in turn are oxidized to nitrates. This process, which occurs in all natural bodies of water, is known as the process of chemical purification. The essence of the change consists in the disappearance or destruction of putrescible substances and their transformation into the stable mineralized nitrates. (7353.)

The so-called nitrogen cycle is a representation of the changes that take place in the nitrogenous substances introduced into water; the albuminoid ammonia first being changed into free ammonia, the free ammonia then being changed into nitrites and nitrates. The green plant life always present in stream water decomposes the nitrates, taking part of the nitrogen to build up their own tissues, part of the nitrogen being given off in a free state. From the advent of cold weather or from other unfavorable circumstances, these algae may die, undergo decomposition and again give albuminoid ammonia. The albuminoid ammonia is then converted into free ammonia, and the cycle so continued. This may take place a number of times in a river water. (7354.)

Under certain circumstances any river into which an excessive amount of nitrogenous matter is emptied will contain throughout a large part of its course an amount of nitrogen in one form or another in excess of that existing in a stream not so laden at the start. Under such conditions the appearance and reappearance of nitrogen as free ammonia, albuminoid ammonia or one or another of these compounds cannot be held to possess the same sanitary significance as under some other conditions. Free ammonia at the mouth of the Illinois River, for example, may be derived from the decomposition of

algae, while free ammonia at Lockport or Bridgeport may be derived from the decomposition of waste substances leaving the human or animal body or discharged into the water in the course of various manufacturing operations. (5984.)

Everything depends, therefore, upon the interpretation of the available chemical data. Under some conditions albuminoid ammonia, free ammonia or nitrites may indicate sewage pollution. Under other conditions these same substances, in the same amounts, may have no bearing on the wholesomeness of water. It is only by taking into account all accessory and environmental factors that on the basis of these determinations the analyst can form any judgment as to the recency or remoteness of pollution. It must be clearly pointed out that the whole point of sanitary chemical water analysis lies in the inferences that are drawn as to the date at which pollution of water occurred. Owing to the fact that disease germs are living organisms which do not find in water favorable conditions for multiplication or development, but perish more or less speedily, the time factor is the all important one. In a water freshly polluted with city sewage living disease germs are more likely to be present than in one polluted at a more distant date. This, in brief, is the whole meaning of chemical sanitary water analysis, that in the hands of an experienced and candid observer the amount of nitrogenous matter and the state in which this nitrogenous matter is found at the time of analysis gives some indication as to the amount and recency of pollution, and hence as to the possible danger of infection.

Accuracy of the Chemical Data.

Although, as elsewhere set forth, witnesses for defendants have used recognized methods of analysis, and it is shown in the evidence that these witnesses have had prolonged and unusual experience in sanitary water analysis, complainant has seen fit to bring to notice certain discrepancies found in the printed tables introduced in evidence by the defendants.

Some of the discrepancies referred to are unquestionably due to difference in time of transportation of wa[illegible] samples sent to the laboratories at Champaign, Illinois, and Chicago. The reduction of nitrates to nitrites, for instance, may occur in a few hours, and the distance of some of the collecting sites upon the Illinois River from the laboratories to which the samples were sent is amply sufficient to account for many of the variations in the analytical figures. Furthermore, any one who has had experience in water analysis knows that differences in collection, in transportation and errors in the process of analysis sometimes occur where a large number of samples are examined, in spite of efforts to obtain uniform and strictly comparable results. (6368.)

It is certainly a fact that many of these determinations are so delicate that even experienced water analysts obtaining samples of water under the conditions in which these samples were collected would be expected to arrive at results that would differ in some cases. These results might differ considerably. The sanitary significance to be attached to such variations, however, is a different matter. Variations of 50 or 100 per cent. in certain constituents of certain waters would have no sanitary importance whatever. The averages of a considerable series of analyses are more important from the sanitary point of view than any single analysis, and this fact is so generally recognized by water analysts that little weight is attached to a single determination. (6369.)

Validity of Weekly Determinations.

Some of complainant's witnesses in this case have, singularly enough, criticised the number of analytical determinations made by witnesses for defendants on the ground that such analyses were not numerous enough or frequent enough to permit of a valid judgment being formed as to the character of the water. Considering the fact abundantly set forth in the evidence, that no such prolonged and exhaustive study of a river water has been made at any time, anywhere in the world, the

objection is in itself a remarkable one. It must also be noted that other witnesses for complainant, as appears *in extenso* in the testimony of Doctors Ravold, Teichmann and Keiser, have not hesitated to base far-reaching conclusions upon analyses even less limited in number and scope than those presented by defendants.

In respect to the intrinsic merits of the question, the statement of Professor Jordan fully shows the position taken by sanitarians. His testimony upon this point is:

"Q. Do you know whether it is the usual practice in this country among analysts to make daily and hourly determinations of a river water for a long period of time in order to determine the sanitary quality of such water?

"A. Reference to some of the recent studies of river water that have been made in this country shows that opinions have been formed and judgments passed on the sanitary character of river water on a smaller number of determinations than would be involved in hourly or even daily examinations.

"Thus I find in the report on water purification investigations carried out under the direction of Mr. G. W. Fuller, in behalf of the Sewage and Water Board of New Orleans, Louisiana, the report being published in 1903, a series of tables showing the turbidity, alkalinity and chlorine contained in the Mississippi River water from October 1, 1900, to December 15, 1900 (page 38).

"I also find a series of tables showing the composition of the Mississippi River water as determined by its examinations between December 10, 1900, and August 17, 1901.

"In another recent investigation of the composition of river water contained in the report of the Filtration Commission of Pittsburg, Pennsylvania, printed in 1889, I find a series of investigations conducted under the supervision of Mr. Allen Hazen, who, I believe, has already testified in this case. In Appendix No. 2 of this report I find the statement: 'It was desired especially to learn about the character of water obtained from various cribs in the Allegheny River.'

"In the next paragraph the statement appears: 'The samples of the Allegheny River at Brilliant were collected about once a week from the beginning of the work until about March 1, 1898. For the next three months samples were collected twice a week, and after June 1, 1898, samples were again collected once a week until the close of the experiments."

"From what I know of the work of Mr. Fuller and Mr. Hazen, I infer that these gentlemen, who have had large experience in undertakings of this character, would not have had these examinations of river water carried out under their direction at daily and weekly intervals during portions of the calendar year if they had not believed that such determinations actually give a basis for a fairly satisfactory judgment of the character of a river water. Mr. Fuller's examinations at Louisville and at Cincinnati, while extending over a longer period are substantially of the same character as those in the latter investigations.

"In European countries, so far as I know, no extended examinations of river water, based on daily and weekly analyses, have been made, which cover so long a period of time as those that have been made in this case.

"It is, therefore, my opinion that the usual practice of those experts having to do with the examination of river waters in this country is based on the belief that an adequate opinion as to the character of the water can be formed by examinations made at intervals as frequent and during periods as long as those indicated in the instances just cited." (6135, 6136.)

Interpretation of Bacterial Data.

It is universally agreed that many diseases of man and the lower animals are caused by small microscopic plants, belonging to the class bacteria. These organisms are widely distributed in nature, being found in air, in water and in soil, upon the bodies of living plants and animals; and, in short, wherever they can find a suitable condition for growth and multiplication.

The majority of bacteria belong to the group of so-called harmless saprophytes, a name applied to those forms of plant life that feed upon lifeless organic matters such as are contained in dead bodies of plants and animals. Saprophytes are distinguished from parasites, which are those forms able to invade the body of some other organism and to obtain their nourishment from the tissues of the host animal or host plant. To the group of parasites belong, of course, the ordinary disease producing microbes.

A similar distinction is that between the pathogenic and non-pathogenic bacteria, the pathogenic bacteria being those that are able, by their presence and metabolic products, to bring about morbid changes within the bodies of plants and animals.

A bacterium that lives as a parasite under some conditions may be a saprophyte under others; as, when the typhoid bacillus, for example, is cultivated in beef broth in a test tube. A pathogenic bacterium likewise may become temporarily or permanently non-pathogenic by loss of its power to produce disease. Many instances of this sort are known. The case of the tubercle bacillus has been cited in the evidence. (6142.) In general, a pathogenic organism, when living outside of an animal body, tends to lose its power to produce disease. It becomes less pathogenic or even non-pathogenic.

Another distinction between groups of bacteria often referred to in the evidence in this case is that between the aerobic and anaerobic organisms. The aerobes are those bacteria able to live and thrive in the presence of free oxygen, while the anaerobes multiply in the absence of oxygen and do not grow in its presence. Anaerobic decomposition, then, is decomposition taking place under conditions where free access of air is excluded.

Certain bacteria secrete or excrete, in the course of their ordinary life activity, chemical substances analogous to urea or carbon dioxide which are poisonous for other living organisms. Some of these poisonous products are toxines, as they are termed, and are responsible for the injury done to human

beings by the growth of bacilli in their tissues. Thus, the diphtheria bacillus growing in the human throat secretes an extraordinarily powerful toxine which is absorbed and damages especially the tissues of the heart.

In many cases the injury inflicted upon the living organisms by the growth of bacteria must be attributed to these poisonous substances rather than to the presence of the germ itself.

In addition to the poisonous products formed in the body of higher animals in which the bacteria are growing as parasites, it is known that many of these bacteria form toxines when grown in broth or other substances outside of the animal body. When two or more kinds of bacteria are growing together, the products of one have been proved to be injurious to the other. The poisonous products are able to pass through the wall of diffusible membranes and when a celloidin sac containing broth cultures of certain bacteria is suspended in the body cavity of an animal, the poisonous substances pass out through the walls of the sac and may cause the death of the animal, while the bacteria themselves are confined by the celloidin membrane.

This point is referred to here for the sake of elucidating conditions that obtained in an experiment conducted by defendants in this case in the water of the Drainage Canal. In this experiment celloidin sacs were used that permitted the egress of the soluble substances formed by the bacteria within the sacs and the ingress of similar substances that might be produced in the free moving water outside, interchange thus taking place precisely as if the bacteria were under normal conditions swimming free in a large body of water.

Water Borne Diseases.

The channel by which disease germs enter the human body is different in different cases. Some bacteria, such as those of blood poisoning, enter the blood stream through a break in the skin. Taken into the normal stomach, these germs would be entirely harmless. In the case of a few diseases of man, the

specific disease germ commonly makes its entrance into the body by being swallowed. When such germs enter a public water supply many persons may become infected at once and an epidemic of so-called explosive character occur. Two diseases are universally recognized by sanitarians and epidemiologists as being conveyed commonly by infected water. These are typhoid fever and Asiatic cholera. It is probable some other diseases, such as the dysentery of tropical countries and certain scattered outbreaks of dysentery in temperate countries, are also spread by infected water supply. These are practically the only cases in which any important role is played by infected water in disseminating disease.

There is no evidence in any scientific treatise, nor is there any creditable evidence in this case, that justifies the assumption that diseases like pneumonia, tuberculosis, lockjaw or appendicitis are ever water borne diseases; and it would, consequently, be imposing upon the time of the Court to enter upon a discussion of them, and to dwell upon them here would be fruitless.

As regards anthrax, or splenic fever, a disease primarily affecting cattle and only rarely transmitted to man, the case is somewhat different. A few instances of water borne infection among cattle have been recorded, notably in connection with the discharge of tannery refuse into a small stream. Not a single case of anthrax in man has ever been traced to water borne infection.

The evidence in this case does not include any statement of the occurrence of a single case of anthrax in the City of St. Louis, or within the State of Missouri, attributable in any way to water infection. The fears expressed by witnesses in this case are, therefore, purely visionary and absolutely without any basis in observed fact.

The Biological Evidence on the Self Purification of Streams.

1. *Colony Count.* Raw sewage—that is, sewage as it issues directly from city sewers—contains enormous numbers of bac-

teria. This is determined by mixing measured quantities of the sewage with nutrient beef jelly, which allows the living germs to develop and to form aggregates or colonies, most of which become, within a few days, plainly visible to the naked eye. By counting these masses or colonies, each of which is presumed to originate from a single germ, the number of living bacteria originally present in the given quantity of sewage is determined.

The number of colonies—known throughout the record as colony count—has been determined by a number of the witnesses testifying in this case. The results show uniformly a large number of colonies present in the waters of the Drainage Canal and upper stretches of the Illinois River, and a much smaller number progressively with the down flow of the stream. While there are often several million bacteria per c.c. recorded for the waters of the Illinois and Michigan Canal, and for the Drainage Canal above Lockport, the Illinois River at Averyville shows only a few thousand in the same quantity of water.

Particular attention is directed to some observations made by Professor Jordan in the waters of the Illinois River between Morris and Ottawa, reference to which will be made subsequently in this brief.

The colony counts, therefore, taken by themselves, show plainly that in the flow between Morris and Peoria the Illinois River frees itself from the enormous number of bacteria introduced through the Desplaines River.

Since the sewage bacteria die out at such a rapid rate, sanitarians and bacteriologists infer that the more delicate disease germs, including typhoid bacilli, die out at least as rapidly as the sewage bacteria.

2. *Bacillus Coli Communis.* The bacillus coli communis, or the colon bacillus, is, as its name implies, a bacterium inhabiting in large numbers that portion of the alimentary tract known as the colon. It is the bacillus commonly found in this situation.

It is found in the intestinal discharges, not only from man,

but from many other of the higher animals; it is found also in waters and soils contaminated with animal excreta. It is found sometimes in the dust of streets. Its occurrence in this situation is probably due to the presence of horse droppings. It is sometimes, though but rarely, found in the air; in pure water, and in the deeper layers of soil it is found if at all in very small numbers. The colon bacillus is exceedingly similar to the typhoid bacillus in many of its morphological and biological characters. In shape, size, motility, lack of spore formation, it resembles the typhoid bacillus so closely that the most experienced bacteriologists have difficulty in distinguishing between these two organisms on the basis of the characters just enumerated. The growth of these two organisms upon beef broth, gelatine and agar is again so similar that by these characters alone it is not possible to distinguish between the two microbes. The typhoid bacillus and the colon bacillus, in fact, belong to a group of bacteria, including a large number of bacteria, both pathogenic and non-pathogenic. The different members of this group, which is known among bacteriologists as the colon typhoid group, differ from one another by relatively slight biological peculiarities. While the typhoid bacillus and the colon bacillus are thus intimately related, there are, nevertheless, certain constant characteristics which enable an experienced observer to distinguish between the two forms. Some of the main points of difference are, that the colon bacillus is able to ferment dextrose with gas production, while the typhoid bacillus, although producing acid from dextrose, is not known under any circumstances to produce gas; when grown in milk the colon bacillus produces acid from the milk sugar, curdling the milk. The typhoid bacillus is not able to do this.

These are some of the fundamental distinctions between these two germs. The colon bacillus is in every respect more hardy than its near relation, the bacillus typhosus. (5996.)

Under a variety of conditions the colon bacillus has been proved to be more hardy than the typhoid bacillus. (5996, 5997.)

From the facts here enumerated it is clear that while the colon bacillus resembles in many important particulars the typhoid bacillus, it is under all conditions in which the viability of these two organisms has been compared a more hardy and more resistent organism. Its longevity under adverse conditions is greater than that of the typhoid bacillus. This fact, and the ease with which it is isolated and identified, combine to render it a particularly significant organism from a sanitary point of view.

Owing to the fact that bacillus coli communis leaves the human body in large numbers in feces, it is one of the prevailing forms in fresh sewage. For this reason bacteriologists regard the presence and relative abundance of bacillus coli communis in water as one of the most delicate, precise and altogether significant indications of recent sewage pollution.

This subject of coli and its sanitary significance was given special consideration by Professor Jordan, who made an extended study of this subject in connection with his work on the Illinois, Mississippi and Missouri Rivers, and his testimony illustrates this question fully.

In his testimony Professor Jordan says:

"As an illustration of the way in which the presence of this organism can be used for demonstrating the existence of pollution of a dangerous character, I may cite from a paper upon 'Municipal Water Supplies and Their Examination,' by Dr. William G. Bissell, of Buffalo, New York, bacteriologist of the Department of Health in Buffalo. This paper was printed in the Philadelphia Medical Journal, August 30, 1902.

"'Two samples were prepared, each representing one-half gallon of water; one was a sample of water from the Niagara River, taken from the tap at Buffalo after it had passed through a sterilized filtering stone of a Pasteur-Chamberland filter. To this sample there was added a small proportion of salt. The other was a sample of Niagara River water collected at Niagara Falls (and in which it was easy to demonstrate the colon bacillus in cubic centimeter amounts of the sample), into which there

was introduced a small amount of human excreta. No data were sent with either sample, except that they were said to be river water. 'Reports came back that the source from which the first sample was obtained was "unsafe for use on account of the high percentages of chlorides," and that the second sample was "wholesome for household use."'

"This illustration suffices to show that it is possible by means of the delicate test for colon bacillus to detect a degree of pollution which might be altogether missed by the use of less delicate and less precise methods.

"So far as I have been able to discover, it is at the present time the prevailing opinion among those bacteriologists who deal with sanitary water analysis that the test for the colon bacillus, properly applied and interpreted, furnishes one of the most satisfactory clews to the sanitary condition of a water.

"In this connection it should be emphasized that it is not so much the presence or absence of bacillus coli communis in a large quantity of water that is significant as it is the relative abundance of this micro-organism.

"I will cite a statement from a recent monograph bearing upon this matter. This monograph is by Dr. William G. Savage, lecturer on bacteriology, University College, Cardiff, Wales; bacteriologist to the Cardiff County Public Health Laboratory. The article is entitled 'The Significance of the Bacillus Coli in Drinking Water,' and appeared in the Journal of Hygiene, 1902, Volume 2, page 320, edited by Professor George H. F. Nuttall, and published by the Cambridge University Press. This author gives extended tables of the examinations of water from various sources for their content in colon bacilli.

"On page 321 the author states that:

"'In such an investigation the three following points must, in my opinion, always be kept in view:

"'1. That it is not so much the presence of B. coli which is of possible value, but the number present. The consideration of the problem is essentially quantitative, and the number of B. coli in a standard amount of water must be considered. This

view is insisted upon by many English bacteriologists, and there can be no doubt of its vital importance in studying the question.'

"In his conclusion, on page 338, the writer states that:

"'The number of B. coli present is an essential factor, but arbitrary standards of the number of this organism allowable per liter are of but little value, and are fraught with considerable possibilities of error, unless the particular kind of water and the local conditions are considered in every case.'

"In further support of the view already expressed as to the significance of bacillus coli in water supplies, I may cite a report of a committee of the American Public Health Association, presented at the Washington meeting of this association October 26 to 30, 1903. An abstract of this report was printed in the Journal of the American Medical Association for November 21, 1903, page 1292.

"This report of the committee on the significance of bacillus coli in water supplies was presented by the chairman, Professor S. C. Prescott, assistant professor of biology at the Massachusetts Institute of Technology. The abstract is in part as follows:

"'To present a statement of the opinion of the committee individually and as a whole, as probably representing the generally accepted views of sanitary bacteriologists as to the significance of B. coli in water, the following questions were sent to each member; the answers appended, except as otherwise stated, were practically as given below:

"'"1. In view of the fact that numerous investigators have found B. coli in nature where it could not be directly traced to sewage or fecal pollution, do you believe that the colon test of water is as safe an index of pollution as it was formerly regarded to be?

"'"Yes, sir.

"'"2. Are you of the opinion that the number of colon bacillus rather than their presence should be used as a criterion of recent sewage pollution?

"'''Yes.

"'''3. To pronounce a water sewage polluted, would you require as evidence that B. coli was present in a majority of 1 cubic centimeter samples?

"'''Yes, in general.'''

"These opinions or the opinions expressed by these writers coincide with my own experience, based on a considerable number of examinations for the presence of bacillus coli communis. It is my judgment that the relative abundance rather than simple presence of this organism should be considered in sanitary water analysis.

"I may add, furthermore, that my own opinion as to the significance of the abundance of bacillus coli communis in the waters of a flowing stream has been greatly strengthened by some recently published investigations in a report on water purification investigation, and on plans proposed for sewerage and waterworks system published by the Sewerage and Water Board of New Orleans, Louisiana, 1903.

"The work included in this report has been largely carried out under the supervision of Mr. G. W. Fuller, of New York, who, I understand, has already testified as a witness in this case.

"I quote from page 47 of this report, paragraph headed 'Bacillus Coli Communis':

"'In waters which contain unpurified sewage, the test for this intestinal organism is of the utmost importance. In the Mississippi River at New Orleans, however, there is evidently so much self-purification effected by natural agencies, such as dilution, sedimentation, etc., that this normal intestinal bacillus was one of the least common of the forms isolated. In about 100 tests with volumes of water varying from 1 to 300 cubic centimeters, its presence was demonstrated only three times, although the larger samples of water were concentrated in a centrifuge before being seeded into the media contained in fermentation tubes.'

"The remarkable fact that the bacillus coli communis was

discovered only rarely in the water of the Mississippi River at this point, even when large amounts of water were tested, illustrates the condition that is likely to prevail in a river water of this character when protected from the entrance of polluting matters during a considerable part of its course. I further quote from page 49 of this New Orleans report:

"'From what goes before, it will be seen that the Mississippi River at New Orleans, as evidenced by the data obtained during this investigation, is unusually pure from a sanitary standpoint. For instance, it is believed that if 100 cubic centimeter samples of water were taken from the Merrimac at Lawrence, the Hudson below the Mohawk, the Schuylkill, the Potomac, the Ohio at Cincinnati, they would show the presence of bacillus coli communis as a rule. Such is not the case with the Mississippi River water at New Orleans, because, as stated above, the opportunities for natural purification are so great during the last few hundred miles of its flow, and the amount of additional pollution received is so small in comparison to the discharge of the river, that the bacteria which one is accustomed to consider to be the normal inhabitants of surface water effectually crowd out those abnormal bacteria which are carried into the river with the drainage from populated and cultivated areas. It must also be remembered that the banks of the Mississippi above New Orleans are protected by levees. These levees also in turn protect the river from contamination, except where sewers exist. Since it is usually more convenient for the towns immediately above New Orleans to carry their drainage away from the river, almost no local pollution exists.'

"It is, in my opinion, certainly a striking and highly remarkable circumstance that the Mississippi River at New Orleans, after receiving countless millions of colon bacilli contributed by the cities of the Ohio, Illinois, Mississippi and Missouri Valleys, together with those on the many tributary streams, and bearing in mind the facts already instanced as to the relatively high longevity of the colon bacillus, should show itself so nearly free from organism of this class.

"This condition furnishes a singular confirmation of the views that have been expressed regarding the sanitary significance of this organism when found in water supplies." (See Vol. 7, pp. 6000 to 6004.)

And again:

"From all my experience upon the value of presumptive tests for B. coli, I am obliged to believe that this test is of high value in sanitary water analysis, and enables conclusions to be drawn as to the presence or absence of the colon bacillus which are in the main thoroughly satisfactory and decisive." (6008.)

And again:

"My experience leads me to adopt the view that the relative abundance of the colon bacillus in water affords the most satisfactory single analytical indication that sanitary science at present possesses as to the sanitary quality of a natural water." (6039.)

This position and these conclusions are confirmed by Professor Theobald Smith, of Harvard, the eminent investigator, who devised the method of colon determination commonly employed at the present time, and made use of by all witnesses testifying on this point in this case.

Professor Smith states that, in his opinion, the colon test is the best method for determining the purity of a water supply that we have at the present time (7293); that this method is applicable to the self-purification of streams and particularly to such a problem as that presented in the Illinois River; and further, that the failure to find the colon bacillus at New Orleans would lead him to think that all other bacteria that are closely related to the colon bacillus, such as typhoid and dysentery bacilli, and the various modifications of para-colon and para-typhoid, had also disappeared. (7296.)

The only divergence of opinion in regard to the colon test as an index of sewage pollution in water is that expressed by Dr. Ravold, a witness who testified for complainant in this case. His testimony upon this point is as follows:

"Q. What, if anything, does the presence of that (colon) bacillus in running waters indicate in streams?

"A. It has been looked upon by bacteriologists as the index to fecal pollution.

"Q. Now, explain what you mean by that?

"A. Whenever these micro-organisms have been found in water the conclusion is reached that the water must contain sewage, either from the intestinal contents of man or animals.

"Q. And it is an indication of sewage in water?

"A. Yes, sir.

"Q. I will ask you to state whether there is any other bacillus that is found in running streams that is an indication also of sewage in water?

"A. There are several, but there really is no good index. There are micro-organisms that are found in sewage steadily, wherever sewage is present; they are present in large numbers, but a true index to the fecal pollution, I don't know a single one.

"Q. Now, do you mean to include in that statement the bacilli (colon) that we have been talking about?

"A. Yes, sir. That is, previous to our work upon the intestinal contents of fishes, these micro-organisms were really looked upon, and I believe it is still held by Professor Jordan, looked upon as an index to fecal pollution, but our own experience robbed it of that dignity. If it is found in a stream steadily, and we know that there are fish in the stream at the same time, which have it in their intestinal contents, and are discharging it from their intestines, then the bacillus coli communis found in that particular water may be either from sewage, from man or from animals or fish." (70.)

As opposed to Dr. Ravold's position, as above set forth, the testimony of Mr. Whipple, a witness called in this case by the complainant, is worthy of reproduction here. It is, in part, as follows:

"Q. Suppose that a stream contained a great number of fish, like the Illinois River, and this organism or bacteria coli communis was found in the fecal matter of fish, would the pres-

ence of bacillus coli communis in such a water be any evidence of sewage pollution?

"A. It is my judgment that the presence of the fish, even though the bacillus coli communis might be found in their intestines, would not materially influence the interpretation to be made from the results of the coli test of the water.

"Q. Why?

"A. Because it has been my experience that the intestines of fish do not ordinarily contain this bacillus, and that if this bacillus is found there it is a case where the bacillus has been derived from the water, and I base my judgment upon considerable personal work which I have done in that direction.

"Q. If the bacillus coli communis was found in fish in the Missouri River, would you disregard its presence there in the fish in considering the coli communis in order to ascertain the sewage pollution?

"A. So far as the presence of the bacillus coli communis in the intestines of a fish influences the presence of the coli communis in the water." (2076.)

Again, Mr. George W. Fuller, a witness called by the complainant in this case, testified upon this subject as follows:

"Q. Does the coli bacillus come from fish?

"A. Well, in my judgment, that is not very much of a practical proposition in these streams out here. I base that on my experience that in mountain streams where fish are very abundant, there does not seem to be anything in the fecal discharge of fish to distort to any very serious degree the practical results to be derived from the colon bacillus tests which I described." (2661.)

It should be noted in this connection that Dr. Ravold failed to report any observations upon the intestinal content of fish caught in unpolluted waters. As a matter of fact, the absence of the colon bacillus in the water of the Mississippi River at New Orleans furnishes convincing proof that the validity of the colon test is not impaired by the presence of fish in river water.

3. *Bacillus Prodigiosus.* In addition to utilizing the evidence afforded by such organisms as B. coli communis normally introduced into watercourses with sewage, attempts have been made by various observers to trace the fate of bacteria in a flowing stream by introducing micro-organisms foreign, or presumed to be foreign, to the water in question. Among the bacteria that have been used for this purpose is one known as bacillus prodigiosus, conspicuous especially for its production of a red pigment. It has been assumed by witnesses for complainant (Ravold, 780) that bacillus prodigiosus was not a normal inhabitant of the watercourses of the Mississippi Valley. Other witnesses, however, have found it in a number of river waters throughout the Central and Western United States. Professor Russell (6473) states that he has found the organism known as bacillus prodigiosus under external conditions in several instances, including a number of unpolluted water supplies. Mr. J. W. Hill (7508) reports finding it twice in investigations of the Ohio River water during 1895 and 1896. Mr. Fuller, a witness for complainant (2665), testifies that it was found in the Ohio River at Cincinnati on one occasion. Professor Jordan (6143) found the typical bacillus prodigiosus, identifying it by all known tests, in water collected from the Illinois River at Morris, November 6, 1899.

This organism cannot, therefore, be regarded as particularly suitable for studying the problem of the self-purification of streams, since there is incontrovertible evidence that it is sometimes found in natural river water.

4. *The Anthrax Bacillus.* Although, as already stated in this brief, several small epidemics of anthrax have been reported among cattle drinking water polluted with tannery refuse, no instance of water borne infection of anthrax in man has ever been known to occur. It is not in evidence that any single inhabitant of the City of St. Louis or the State of Missouri has ever died from anthrax. Danger from this source must therefore be regarded as so remote and problematical as not to warrant serious consideration in this case.

5. *The Bacillus of Tetanus, or Lockjaw.* The tetanus bacillus is an anaerobic organism thriving only in the absence of relative scarcity of oxygen. Man is usually infected with this germ by some deep and ragged wound that forces the tetanus bacillus present on the surface of the skin deep into the tissues. The familiar Fourth of July tetanus from toy pistols is the most common form of the disease in the United States. Tetanus is never, so far as known, a water borne disease. The bacillus is common in horse dung, and consequently in the dust of city streets. To attribute a case of tetanus occurring in the City of St. Louis to a tetanus bacillus brought to that city in the waters of the Illinois River would, therefore, be grotesquely irrelevant.

6. *Cholera Spirillum.* The germ of Asiatic cholera is known to be conveyed for short distances in water, and drinking water is the usual means by which cholera is spread. The cholera spirillum is regarded by bacteriologists as a rather delicate microbe, succumbing readily to various injurious influences. No evidence derived from experiment or observation has been introduced in this case indicating that the germ is able to retain its vitality in water for a period sufficiently long to enable it to pass from the sewers of Chicago to the intake tower of the City of St. Louis. It may be noted also that Asiatic cholera has in recent years shown itself comparatively easily controlled by sanitary measures and precautions, and that when the known safeguards are used civilized countries have little to dread from the recurrence of this disease.

The famous outbreak of cholera in 1892-3 at Hamburg, Germany, was due to a badly infected water supply. The River Elbe, from which the supply was at that time taken in an unfiltered condition, was highly polluted with the city's own sewage, which was freshly mingled at each tide with the water at the intakes. In this case the pollution of the water with the city's own sewage was immediate and direct, both in point of time and in that of distance. The conditions obtaining in the Hamburg epidemic were in no wise comparable with the situation of St. Louis and Chicago. This outbreak of cholera in Hamburg is

the only water borne epidemic of cholera testified to in this case, and owing to the close approximation of the point of infection and the point of water supply, it can have no practical or theoretical bearing upon the issues here involved.

7. *Typhoid Bacillus.* Typhoid fever is the most common water borne disease of temperate countries. It is not by any means true, however, that water is the only vehicle of infection. Many kinds of food, especially such as are habitually taken in an uncooked state, may convey the specific germ into the alimentary tract. Raw milk, raw oysters, lettuce, celery and the like have been shown to be capable of transmitting the infection. Two very important sources of infection have been fully recognized only in recent years. The experience with typhoid fever in the United States army military camps at the time of the Spanish-American War furnished a remarkable example of the way in which typhoid fever may be spread through the agency of flies. This is fully set forth in the testimony of Professors Vaughan and Dock, who personally investigated the conditions prevailing in the camps, and whose evidence will be referred to later. Attention must also be called to the discovery by Dr. Alice Hamilton of typhoid bacilli on the bodies of flies caught in infected districts in a large city. (6271.) Sanitarians and epidemiologists now universally recognize the importance of this source of typhoid infection, long overlooked.

A second and very common mode of infection in typhoid fever is that of contact or comrade infection. Persons living in the same house with a typhoid fever patient are especially exposed to this kind of infection. The use of common table utensils, of towels, drinking cups, bed clothing and the like, constitutes a very common means of spread. This kind of infection on a large scale is again illustrated in the experience of Professor Vaughan, as will be subsequently detailed in his evidence. Epidemiologists are now agreed that these modes of infection in typhoid fever are much more frequent than was formerly supposed, and a large part of the typhoid fever obtaining in any community must be attributed to such sources.

The typhoid bacillus, as has been elsewhere set forth, closely resembles the colon bacillus in many fundamental qualities. It is, however, less resistent than the colon bacillus to various destructive influences. Introduced into water, into soil or dried on particles of cloth or metal, it perishes more speedily than the latter. Various factors influence the longevity of the typhoid bacillus as of all organisms. The temperature of the medium in which it lives, the abundance or scarcity of food supply, the competition or lack of competition of other organisms, and many other factors determine in part the precise length of life of a given typhoid bacillus.

Great confusion has been introduced into studies upon the longevity of these organisms by failure to take into account the action of these different factors. The laboratory experiments made to determine the longevity of the typhoid bacillus differ in many important particulars, such as the nature and size of the container used, the number of typhoid bacilli introduced, the amount of food material present in the fluid in which the typhoid bacilli are suspended, the temperature at which the organisms are kept—these and many other factors have an undoubted influence upon the longevity of the typhoid organism, and one reason for the conflicting results obtained by different experimenters, as reported in the evidence in this case, is due to the lack of comparability of the conditions under which they worked.

Peculiarly important in this connection, as pointed out by Professor Jordan in his testimony (6159) is the nature of the container in which the typhoid bacilli are suspended with a view of determining their longevity. In practically all the laboratory experiments that had been made prior to this case and that are discussed by various witnesses in the evidence, glass bottles have been used to hold the water or other fluid in which typhoid bacillus have been placed. It has been shown that when the water in such glass bottles is heated for purposes of sterilization in such experiments, or even allowed to stand in the bottle during the period that the experiments are being conducted, substances are dissolved from the glass that favor

continued longevity on the part of the typhoid bacillus. Laboratory experiments are therefore much more favorable to continued longevity of a typhoid bacillus than conditions in nature. It was to obviate this grave and radical source of error in the previous experimental work on the longevity of typhoid bacillus that witnesses for defendants devised and employed containers not open to criticism on this score. The use of parchment and celloidin sacs referred to in detail in another part of this brief effectually removes any objection that the bacilli contained in such sacs are not under normal and natural conditions. Such sacs, as is well known, and as has been demonstrated in case of the specific containers employed by witnesses for defendant, favor the process of osmosis or interchange of substances in solution in the sac with those in the fluid in which the sacs are suspended; in this case the waters of the Chicago River, the Chicago Drainage Canal and the Illinois River. In this way natural conditions are precisely reproduced and the longevity conferring power of the glass bottle altogether eliminated.

The results obtained in these experiments by defendants' witnesses upon the longevity of typhoid bacillus in the Chicago River, Chicago Drainage Canal and the Illinois River are in complete harmony with the epidemiological evidence, which indicates that typhoid bacilli introduced into water survive there for only a few days. This does not imply, however, that typhoid bacilli may not live longer in fecal accumulations and masses of filth than they do suspended in water. In fact, many observers have shown that typhoid bacilli can live for weeks or longer in such fecal accumulations. Many classic epidemics of typhoid fever have been traced to infection of this character, and the alleged and assumed cases of typhoid infection coming from water during long periods of time are explained more in accordance with all known facts and observations by supposing that bacilli from such fecal accumulations on the banks of a stream are washed continuously or at intervals into the water supply than by assuming that the bacilli survive for any considerable period after entering the water.

All of the available evidence on the longevity of the typhoid bacillus, the point which beyond all others is an issue in this case, indicates that this organism can persist in natural bodies of water in a living and virulent condition for only a few days.

Furthermore, evidence has been introduced and is available from other sources to the effect that while the typhoid bacillus lives for a short time when introduced into polluted waters—that is, in waters containing considerable amounts of organic matter and large numbers of bacteria—it dies off more speedily than when it finds its way into relatively pure waters.

In view of these facts, it is apparent that a typhoid bacillus introduced into the water of the Drainage Canal is not likely to live so long as one introduced into a less highly polluted fluid. The longevity of the typhoid bacillus under conditions as they prevail in this controversy, and as applied to the issues in this case, will be discussed in detail under a separate heading, but the foregoing explanation is offered merely as a guide for the interpretation of the bacterial evidence that follows.

Epidemics.

Evidence as to the longevity of the typhoid bacillus in water under natural conditions may be grouped under two heads: First, the bacteriological experiments made under conditions identical with or most closely simulating conditions that obtain in nature; second, that derived from a study of water borne epidemics of typhoid fever. The epidemiological evidence may be first considered. Most of the classical epidemics of typhoid fever that are recorded in treatises on hygiene and sanitation and have been discussed by witnesses in this case, have been due to infectious material that has traveled only a short distance, a distance as a rule not exceeding thirty miles. Among these may be mentioned such well known, severe and explosive outbreaks as that of Plymouth, Pennsylvania; Ithaca, New York; Butler, Pennsylvania, and others of a like character. As contrasted with these universally recognized and classic

water borne epidemics of typhoid fever attributed to nearby pollution, witnesses for complainant have introduced and commented upon outbreaks of typhoid fever, in which, in their opinion, the infecting matters traveled a considerable distance before reaching the water consumer. These are, specifically, the Detroit epidemic, the Washington epidemic, the prevalence of typhoid fever at Pittsburg and at Covington, Kentucky.

In each and all of these cases the evidence adduced in support of the contention of water carriage over a considerable distance has been gathered, interpreted and judged by witnesses appearing for complainant.

The emphasis that has been laid upon these cases, and the fullness with which they are set forth in the record, enables defendants to show the insecure character of the evidence relied upon by witnesses for complainant as a basis for their expressed opinions and conclusions. Not one of these alleged cases of water borne epidemics, when scrutinized in the light of the evidence presented in this case, will bear the interpretation placed upon it by those of complainant's witnesses who report the occurrence.

This topic is treated more fully than its intrinsic importance deserves, because complainant's witnesses have allowed these cases to influence them very materially in forming the judgments that they have expressed.

These epidemics will be discussed separately and the evidence analyzed under the following headings:

Detroit Epidemic.

All the facts and circumstances in connection with the so-called Detroit epidemic have been introduced into the evidence in this case, but before entering upon a discussion of the facts, reference will be made in the testimony showing that complainant's witnesses accepted the Detroit epidemic as a well estab lished example of typhoid infection being carried from Port Huron, through Lake St. Clair, to Detroit, causing an epidemic of typhoid fever in the latter city.

Dr. Ravold, in his testimony, on page 904, stated in answer to the following question:

"Q. So that bacteriologists in ascertaining the cause of typhoid epidemics have not, up to this time, definitely located the cause of the infection at a greater distance than between Detroit and Port Huron?

"A. Yes, sir; simply because, as I said this morning, it is impossible even if typhoid bacilli were found at the place of entrance of sewage and then typhoid bacilli found in the water below, it could not be proven that they came from this particular place, because the bacillus is not labeled, has no sign or mark on it by which it could be distinguished from a typhoid germ coming from any other source.

"Q. Then there is no ascertained case of where the infection was brought further than the case that you have just mentioned?

"A. I know of none."

And again, on page 867, he was asked:

"Q. What per cent. of accredited cases that are reported in the books show the source of typhoid fever from water pollution to be exceeding fifty miles?

"A. Well, I cannot say that definitely, and it would be an extremely difficult thing to do on account of the complexity of modern life.

* * * * * *

"Q. Now, name one if you have one in mind.

"A. I have one in mind.

"Q. Where was that?

"A. Dredging at St. Clair.

"Q. How?

"A. Dredging of the St. Clair River, and the typhoid fever epidemic following in Detroit; that has been reported by Dr. Williams. * * * There were typhoid fever cases up the river above that. Typhoid fever discharges went into the river. They dredged into the silt and sludge and slime at the mouth of the Wolf River. This sludge was stirred up some time

afterwards and carried across Lake St. Clair into the water supply."

And again he states:

"We had a remarkable case, which I mentioned this morning, at Detroit, in which a mass of filth and sewage which had collected at the mouth of the Wolf River was cleared away and carried across Lake St. Clair into the water supply at Detroit, causing typhoid fever."

This so-called epidemic of typhoid at Detroit was frequently quoted by Dr. Ravold in his testimony as being unquestionably established. (867-8, 897, 952.)

Mr. George C. Whipple, a witness for complainant, cited the Detroit epidemic as an incident where the typhoid germs had remained in the water for at least ten and one-half days prior to the entrance of the water into the service pipes of a community where the epidemic prevailed. (1999.) And also he referred to the so-called Detroit epidemic as illustrating the distance traveled by the typhoid germ. (2128.)

Professor William T. Sedgwick, one of the complainant's most important witnesses in this case, in attempting to show that the removal of deposits of such matter from the bed of streams resulted in causing typhoid epidemic, referred to the Detroit epidemic in this language:

"The best example undoubtedly that we have of such an effect in a stream, and it happens to be one that was combined with a slack water lake, so that we have the double demonstration in one case, is the well known instance of typhoid fever in Detroit, resulting from the dredging of the Black River at Port Huron, which caused the carriage of detached sediment down St. Clair River through the St. Clair Lake and into the intake of the Detroit waterworks. I think that was in 1892, if I remember right. That is probably the most striking case we have on record. It was very thoroughly investigated, and I am familiar with the data upon which the conclusions were based, and in my opinion it is a well established case, and it is the best that I know." (2199.)

And again, Professor Sedgwick, in citing the case of typhoid germs having been carried in water and causing infection, he states:

"I think the greatest distance known, that I now recall, is that of the Detroit epidemic, in which it was well established—apparently well established—that the infection was conveyed for about fifty-seven miles." (2270.)

And again, Professor Sedgwick in citing the case of typhoid fever which was certainly traceable to typhoid bacilli which had existed for a length of time in the sediment of a running stream, referred to the "Detroit case, which to the best of his judgment and belief, was conclusively traced to the stirring of sediment in the Black River near the St. Clair River." (2309.)

From the testimony above referred to, it can easily be seen what an impression the so-called Detroit epidemic made upon complainant's witnesses, and how strongly they relied upon that so-called epidemic in order to illustrate or to draw a comparison of the length of time a typhoid germ would live in water or in sediment, or the distance it could travel and yet be able to carry infection.

Mr. Gardner Stewart Williams, one of complainant's witnesses, is responsible for having discovered the so-called Detroit epidemic, and he claims to have established that an epidemic of typhoid fever in Detroit was traced to the dredging of the Black River at Port Huron, a distance of fifty-seven miles from the intake of the Detroit waterworks.

In order to present to the Court the facts in regard to this so-called Detroit epidemic, as the same appears in evidence the testimony of Mr. Williams, who is authority for this epidemic, is set out in full, as follows:

"Q. Mr. Williams, do you know of any case where a similarly diluted mixture of suspended solids from sewage matter has produced typhoid fever?

"A. I do; at Detroit, in 1892.

"Q. Will you briefly describe the circumstances of that epidemic and the conditions involved in it, and which led up

to it? If you have personal knowledge of those facts, please state that.

"A. I have personal knowledge of the facts in question, inasmuch as I investigated the outbreak of typhoid fever in Detroit which followed the occurrence to which I have reference.

"The water supply of the City of Detroit is drawn from the American channel of the Detroit River, at the head of the river, or at the foot of Lake St. Clair. Detroit River, as you know, is one of the links in the connecting waters between the upper lakes, Huron, Michigan and Superior, and the lower lakes, Erie and Ontario, and is the natural outlet of the upper Great Lakes to the sea. The water from Lake Huron enters the St. Clair River and flows through it a distance of about thirty-five miles to the delta of the St. Clair River, when it discharges into Lake St. Clair. Lake St. Clair is nearly circular in form, being twenty-four miles wide and, including its delta, about twenty-four miles in length, measured in the direction of flow. The water supply of Detroit is taken practically from the lake, or from the river a few hundred feet below the point where it takes its origin in Lake St. Clair.

"In the year 1890 the number of deaths in the City of Detroit from typhoid fever were thirty-nine; in the year 1892 the number of deaths from typhoid fever in the City of Detroit were 209. This remarkable increase was such as to cause Detroit for that year to take rank among those cities which have had the highest death rates from typhoid fever in America; there are but one or two of our large cities that have had death rates notably higher than this, one of them being Chicago. An examination of the records showed that this epidemic began in June, during which month there were thirty-eight deaths by typhoid fever. As the civil engineer to the Board of Water Commissioners of Detroit, it was very natural that my attention should be called to this condition of affairs, as many people attributed the cause of the epidemic to the water supply, and I started to ascertain, if it were possible, where such a remarkable infection could have come from so suddenly and so unex-

pectedly. After an extended investigation, I found that the epidemic was undoubtedly caused as a result of improvements to the channel of Black River, which flows into St. Clair River near its head, at Port Huron, a distance of about fifty-seven miles from the intake of the Detroit waterworks. I found that Black River, which was a sluggish stream having ordinarily no current whatever, and only in times of heavy rains a perceptible current, had been for years receiving the sewage from the City of Port Huron, through the center of which it flows. In order to improve the harbor of Port Huron, which was virtually the lower portion of Black River, the United States Government had caused the river to be dredged during the early months of 1892, and in the process of that dredging had removed deposits from near the mouths of the sewers, which ranged in depth from a foot to seven or eight feet, and according to the testimony of some of those who lived along the banks to as much as ten feet in depth. This material was loaded upon scows and transported out into the St. Clair River, where it was discharged or dumped into the stream at a point, as I have already stated, about fifty-seven miles above the intake of the Detroit waterworks. I found upon further investigation that this work had been begun during 1891, and that conditions were such that this particularly highly infectious deposit of material was reached right at the beginning of the operations in 1892, so that this fully explained the sudden outbreak of typhoid fever in Detroit, it having been carried through the water of the St. Clair River, and through Lake St. Clair, to the intakes of the Detroit waterworks, and thence distributed to the consumers throughout the city, with the result above mentioned." (2439, 2440-41.)

* * * * * *

"The current in the St. Clair Lake is not perceptible to the eye. The time required is not less than eight days, and would have arrived there in twelve to fourteen days." (2441-3.)

* * * * * *

"Seventy-five per cent. of typhoid cases will incubate in from ten to fifteen days' time after infection." (2444.)

* * * * * *

"I found that, making allowances already stated for the time required for the infection to come from the point at Port Huron to Detroit, allowing for incubation, allowing time for the patient to die, that the sum of such times agreed within twenty-four hours of the time which had elapsed from the deposit of the dredge material and the time when there were four deaths from typhoid fever in Detroit." (2445.)

* * * * * *

"There had been typhoid fever in Port Huron in September and October, 1891, as shown by the records of the State Board of Health of Michigan, which facts have been communicated to me by the secretary." (2450.)

* * * * * *

"Dredging began April 16, 1892, and the work continued all through the year, but the dredging of the particularly infectious matter ended in a comparatively short time, a matter of a few weeks." (2451.)

* * * * * *

"After the most careful investigation which it was possible for me to make, which included conversations with physicians who treated cases during this epidemic, the studies of rainfall, general precipitation and temperature, and the distribution of the cases throughout the city with relation to possible infection from previous cases, and a consideration of all other suggested sources of typhoid infection, it was impossible for me to find any cause which could explain or begin to explain such an outbreak of typhoid as occurred in the month of June, 1892." (2453-4.)

"In consideration of the fact that the most recent known cases of typhoid fever preceding the time of the dredging in the spring of 1892 at Port Huron were those reported in September and October, 1891, to the Michigan State Board of

Health, and in view of the fact that inquiries of the Board of Health of Port Huron and of the health officer of said city and of leading physicians there failed to establish the existence of typhoid fever in Port Huron subsequent to that time and previous to the beginning of the dredging in the spring of 1892, I am entirely satisfied that some of the infection in the sewage matter dredged in the spring of 1892 had remained or lived in that material for three or four months at least, and I think it entirely probable that much of it had lived a very much longer time." (2459.)

"I am convinced that they (meaning typhoid in Detroit) were very largely caused by the stirring up of the material on the bottom and sides of the St. Clair River and Lake St. Clair and at the head of the Detroit River itself, which had come there as a result of the dredging of moderately infected material at the mouth of Black River during the fall of 1891, and had remained on the bottom or in the layer of water adjacent to the bottom during the intervening period." (2460.)

The foregoing testimony is the direct examination of Mr. Williams, stating all the facts that he ascertained in regard to the epidemic of typhoid at Detroit being directly traceable to the dredging of the Black River at Port Huron. It will be observed from this statement of facts that the impression left from reading it would be that Mr. Williams made this determination at the time that the epidemic occurred.

The cross-examination of Mr. Williams elicits the information upon which he bases his conclusions and the time when those investigations were made:

"Q. When did you investigate the epidemic of typhoid fever which appeared in Detroit in 1892?

"A. From 1895 to the present time.

"Q. At the time of this epidemic you made no kind of investigation of it?

"A. No, sir." (2487.)

* * * * * *

"Q. Where did you learn that the harbor of Port Huron had been dredged?

"A. At a meeting of the Detroit Engineering Society, held at the Hotel St. Clair, in Detroit, was the first I knew off it.

"Q. At what time?

"A. I think it was some time in 1896 or possibly 1897.

* * * * * *

"Q. So that the first you knew that the harbor of Port Huron had been dredged was in 1896 or 1897?

"A. Yes, sir.

* * * * * *

"Q. Did you go to Port Huron in 1896 to investigate the dredging done there in 1892 and 1891?

"A. No, sir.

"Q. Did you ascertain in Port Huron the number of cases of typhoid fever or deaths from typhoid fever in 1890 or in the preceding year?

"A. As I remember the matter now, there were no records available in 1890, or during the preceding years.

"Q. Were there any records available in 1891 at Port Huron as to the deaths from typhoid fever?

"A. The records in 1891, I believe, were obtained from the Michigan State Board of Health.

"Q. How the Michigan State Board of Health obtained it you do not know?

"A. They obtained it from the report of the health officer or person in Port Huron reporting the appearance of typhoid to them.

"Q. Whether that report was correct or not you do not know?

"A. I certainly do not.

"Q. Do you know how many cases of typhoid fever there had been in Port Huron in 1891, prior to November?

"A. My recollection is there had been *two cases reported.*

"Q. Do you know how many cases had been reported in 1890, during the entire year?

"A. *I do not.* My impression is there had been none reported.

"Q. Do you know as to 1889 or any preceding year?

"A. I do not. * * * When I began this investigation I didn't know of any deaths in Port Huron from typhoid fever.

"Q. And you do not know of any now, do you?

"A. *I was not personally acquainted with any persons who died from typhoid fever in Port Huron.*

"Q. Do you know from the records, and if so from what records, of the existence of typhoid fever in Port Huron prior to November, 1891, with the exception of the two cases which you recollect?

"A. *I do not.*

"Q. *So that absolutely you never did know and do not now know whether there were more than two cases of typhoid fever in Port Huron prior to November,* 1891?

"A. *I do not.*

* * * * * *

"Q. Were those cases of deaths or merely sickness?

"A. I cannot positively recollect, but my impression is they were cases, not deaths.

* * * * * *

"Q. During the summer seasons aren't the flats of Lake St. Clair, its marshes, frequented by from two to three thousand people daily, at the resorts and in the clubhouses, in the occupation of fishing?

"A. That is a larger number than I should estimate were there.

* * * * * *

"Q. So that there is a considerable number of constantly changing population upon Lake St. Clair during the summer seasons?

"A. Yes. * * * *Or upon the upper portion of Lake St. Clair—that is, upon the delta of the St. Clair River.*

"Q. *And the dejecta of these people goes directly into the water, doesn't it?*

"A. *I think that is generally the case. In fact, I know of no other disposition of it.*

* * * * * *

"Q. What amount in cubic feet would there be in Port Huron for one year of fecal and urinal discharge into the sewers?

"A. I will be unable to answer that question, because I am not informed of even approximately the number of persons who use the sewers of Port Huron, and therefore it would be impossible for me to make an estimate in answer to the question.

"Q. Had you, in 1890 or 1891 or 1892, sufficient familiarity with the City of Port Huron to make a guess as to the number of people whose sewage was discharged into the sewers of Port Huron?

"A. I think not.

"Q. Then as to the volume or amount of such discharges you have no kind of an idea?

"A. No, sir, except that there were such discharges.

* * * * * *

"Q. Would you say in your best opinion that it would be fair to estimate that five thousand people discharged their household sewage into the sewers of Port Huron in 1890 and 1891?

"A. I think it is possible.

* * * * * *

"Q. If such assumption is fair, what amount in cubic feet would you estimate there was of dejecta and urinal discharges from those five thousand people, making the estimate upon some basis which engineers or sanitarians assume?

"A. Oh, between six thousand and seven thousand cubic feet.

"Q. How many cubic yards would that be?

"A. Oh, about 230 to 250, or less than one-half the amount, or about one-half of the amount that was usually dredged in a

day during the dredging of the Black River in 1892. I should expect it would be fair to make a division of the amounts that I have computed by 6 to get the probable delivery in the two months of the year in question.

"Q. Or, substantially, in round numbers, forty cubic yards in the two months?

"A. Just about that, substantially, yes, sir. That would be 10,600 yards substantially in round numbers in April and May of dredged material.

* * * * * *

"Q. Of the assumed 10,600 yards of material dredged from the harbor of Port Huron, some forty odd cubic yards might possible be a fair estimate of the amount of solids in the household sewage coming from the bodies of persons using the sewers of Port Huron?

"A. I would say that I think that forty cubic yards of about 15,000 yards would be a correct statement of the case, or an approximately correct statement of the case.

"Q. Well, assuming that the sewage discharge of the kind spoken of, household sewage, in solids, was 230 to 250 cubic yards per year, you would have a fair estimate, you think, of the solids in cubic yards for the City of Port Huron during the year?

"A. I think it is a reasonable estimate.

* * * * * *

"Q. If such a body of water were regularly and continuously polluted one part in one million, how many cubic feet of pollution would have to be put into the water each day to make one part?

"A. On that assumption, 15,552 cubic feet.

"Q. That is to say, in order to regularly, systematically and scientifically pollute the body of water flowing past Port Huron in the St. Clair River for one day of twenty-four hours, there would have to be 15,552 cubic feet of polluted matter to make one part in a million of pollution?

"A. That is correct, sir.

* * * * * *

"Q. What per cent. of pollution of 933,120,000,000 cubic feet of water is forty cubic yards of solid material, stated in part per million?

"A. About 108/10,000ths.

"Q. 108/10,000ths of 1 per cent.?

"A. 108/10,000ths of one part per million.

"Q. Do you want to be understood as saying on the basis of these figures that if there was the dejecta of two typhoid patients put in some time about the 1st of April, 1892, in forty cubic yards of solid sewage, from the bodies of people, in 933,120,000,000 cubic feet of water, which would travel fifty-seven miles, that that dejecta would pollute the entire body of water during any considerable portion of that time, or any portion of it?

"A. Considering the fact that the number of bacteria found in the excrement of typhoid patients has been on the average about 200,000 million per day, and that if these patients were sick with typhoid fever and recovered they would each have been discharging that excrement so charged with infection for a period of sixty days, and considering that there were assumed to be two patients, we find that there would have been probably discharged into the sewers of Port Huron, and from there possibly in Black River and the material dredged therefrom, 24 million million bacteria, which would have been sufficient to put about 27 bacteria into every cubic foot of water discharged under the conditions assumed; it therefore seems to me possible that the infection might have been so distributed.

"Q. Then, assuming that the volume of water in the St. Clair River passing Port Huron in a day was 15,552 million, what per cent. of it was pumped into the Detroit waterworks?

"A. Three-hundredths of 1 per cent., I think.

"Q. Twenty-seven bacteria or typhoid bacillus to a cubic foot of water would be about four individual separate bacteria —roughly speaking—to a gallon?

"A. Yes.

"Q. Assuming that the number of bacteria you have mentioned, namely, 27 to a cubic foot of water, was equally distributed throughout the entire volume of water flowing out of the St. Clair River into the Lake St. Clair, and therefrom through the Detroit River to the intake at Detroit, do you want to be understood as saying that those four bacteria in a gallon of water, traveling fifty-seven miles, would live and be virulent?

"A. I see no reason why some of them might not live and be virulent.

"Q. Do you see any reason based on any prior knowledge why they should? I am not asking you for details of any specific case, but on any knowledge that you have now, of the state of the science or art prior to May, 1892, do you see any reason why they should?

"A. Yes, I do. In 1888 experiments showed that in ordinary potable waters the germs had been found alive after two weeks, and it would not take them two weeks to come from Port Huron to Detroit under the circumstances assumed.

* * * * * *

"Q. Do you know when these two people died of typhoid fever in Port Huron?

"A. I don't know that they died.

"Q. You have heard that they died?

"A. No, sir.

"Q. Do you know, then, whether these two cases of which you have heard recovered?

"A. I do not.

"Q. Do you know whether the discharges from their bodies were cast into the sewers of Port Huron.

"A. *I do not.*

"Q. Do you know whether the discharges from their bodies were destroyed?

"A. *I do not.*

"Q. Or disinfected?

"A. *I do not.*

"Q. Without stating what you may have in your mind, do you wish to be understood, as a sanitary expert, epidemiologist and sanitary engineer, that under the facts and figures elicited by your cross-examination, you are still of the opinion that typhoid fever resulted from the dredging of the harbor of Port Huron and the mouth of the Black River in 1892?

"A. I wish to be understood as saying that it is my belief that the typhoid fever in 1892 was very largely caused by the dredging of Black River in Port Huron during the same year. (2487, 90, 91, 92, 93, 94, 99, 2514.)

The foregoing testimony substantially states all the facts upon which the Detroit epidemic is based, and it will be noticed that Mr. Williams, who rescued this epidemic from oblivion, and from the facts as he has detailed them in this case, gave it as his judgment that the epidemic of typhoid in Detroit was due to the dredging of the Black River at Port Huron, did it when he did not know whether the discharges from the body of any typhoid patients in the City of Port Huron had been emptied into the sewers of that city or not.

If the cause of an epidemic can be establsihed upon information as limited as was the information of Mr. Williams in regard to the Detroit epidemic, from an investigation made five years after the epidemic had subsided, it merely illustrates the remarkable method of reasoning that has been employed in this case by some of the experts for the complainant, who have placed themselves upon record in their testimony as saying that the Detroit case is, to the best of their judgment and belief, conclusively traced to the stirring of sediment in the Black River near the St. Clair River.

The cross-examination of Mr. Williams developed additional interesting facts in regard to his knowledge of conditions existing in connection with the so-called Detroit epidemic in 1892, as is evidenced by the following testimony:

"Q. And that the period from the deposit of infectious ma-

terial to the four deaths occurring corresponded within twenty-four hours, you stated, of the time allowance for incubation?

"A. For the transmission, incubation and death.

"Q. How long had those patients been sick with typhoid fever?

"A. *I couldn't say.*

"Q. How long after a person contracts typhoid fever before they pass the danger point?

"A. That is rather hard to say.

"Q. Well, not knowing how long these four patients had been down with typhoid fever before they died, how did you make your conclusions as to the time of incubations, between the deposit and their death, as being an accurate judgment?

"A. Well, having made a study of the statistics of some thousands of typhoid cases, and determining therefrom the ordinary average period elapsing from the time of infection to the time of death, or from the time of taking down to the time of death, and finding the average period in a very large number of cases of typhoid, I felt warranted in assuming and applying that period to the cases in question.

"Q. *Regardless of knowing whether those patients had been sick for two or three months prior to death or not?*

"A. *Certainly, yes.*

"Q. Assuming it is not an improbability or an impossibility that the date of the four deaths under consideration had occurred after an illness of, say, two or three months' duration, would that make any difference in your conclusions?

"A. I think I can safely eliminate those four deaths without vitiating my conclusions or causing me to change my views in the matter." (2554.)

The defendants contend that the facts introduced in evidence upon which Mr. Williams drew the conclusion that the typhoid epidemic of Detroit was attributed to the dredging of the Black River at Port Huron, have not been established, and in fact the dredging of that river does not raise even a presumption that it was the cause of the typhoid epidemic in Detroit in 1890. No

consideration was given to the number of people boating upon the Detroit River or upon Lake St. Clair, or the possibility of any of the people upon the river or the lake having typhoid fever, and the only information that he gives us is the presence of two typhoid cases, of which he had no personal knowledge; neither did he know whether the dejecta were emptied into the Black River or not, and on these meager data he announces it as an established fact that typhoid fever germs came from the Black River at Port Huron and infected the water supply of Detroit, a distance of fifty-seven miles, and caused the epidemic of typhoid fever in the City of Detroit. And his conclusions, for the purposes of illustration, were accepted by Professor Sedgwick, Dr. Ravold and Mr. Whipple as established, and applied to the problems in this case.

It is a significant fact that the learned attorneys representing the complainant in this case were not satisfied that the epidemic in Detroit had been established as being due to infection coming from Port Huron, and for that reason brought local doctors from Port Huron to St. Louis and examined them as to typhoid fever conditions existing in that city in the years 1890 and 1891.

Among those physicians were Dr. Hiram R. Mills, Dr. Charles B. Stockwell and Dr. Oliver Stewart, and their testimony, instead of sustaining the theory upon which is predicated the so-called Detroit epidemic, cast an additional shadow of doubt upon its validity; their testimony is worthy of consideration in part.

Dr. Hiram R. Mills, a practicing physician of Port Huron, testified that in 1891 he attended four cases of typhoid fever. The dejecta of all were ordered to be disinfected with carbolic acid and copperas, and so far as he knew it was done. He could not state positively as to whether the houses wherein these patients sick with typhoid resided were connected with sewers or not. (2689-92.)

As far as the cases, both for 1890 and 1891 were concerned, his testimony does not show that the dejecta of any typhoid

patient, unsterilized, entered into the sewers leading into the Black River.

Dr. Charles B. Stockwell, a physician in Port Huron, testified that he had three cases of typhoid in 1892. The house of one of the patients had direct connection with the Black River by private sewer. The other sewered into the St. Clair River, and as to the third patient he was not certain whether the sewage went into Indian Creek or not. (2718-19.)

Dr. Oliver Stewart stated that in 1889 he had five cases, three of them in August and one in September, and in 1890 he had five cases, four of which were in one house, in September, the disease running into October, and one case on Ninth Street in September. In 1891 he had four cases, one in September and three in October, one being a tramp in the hospital. One of the houses had sewer connection, but he did not know as to the rest. The excreta were ordered disinfected, and he believed that his orders had been carried out. (2721-24.)

It will be observed that of the number of typhoid cases testified to by those three doctors as occuring in Port Huron in 1890 and 1891, only one patient whose excreta were not sterilized dwelt in a house that was connected with a sewer leading into the Black River.

Mr. E. J. Hayes, United States Engineer, was put on the stand in regard to the dredging and testified in regard to the current of the Black River as follows:

"Q. What was the current of the Black River?

"A. During the summer months there was no current; in the spring there was a freshet which took the ice and everything out of it." (2756.)

The testimony of the engineer above quoted to the effect that the Black River "had no current in the summer, but in the spring there was a freshet which took the ice and everything out of it," leaves small hope for the theory of Mr. Williams that the dejecta of one typhoid patient or of two patients could have formed such a deposit of infected material in the Black River as to pollute and contaminate the enormous volume of water passing through the St. Clair River.

Of this so-called Detroit epidemic, defendants would like to submit to the Court the testimony of witnesses called in behalf of the defendants in this case.

Professor Jordan on page 6319 stated:

"I have read the testimony that has been given in this case regarding the dredging of the Black River at Port Huron and its supposed connection with the outbreak of typhoid fever in Detroit. As an epidemiologist I do not consider the fact established beyond a reasonable doubt that the epidemic at Detroit was due to the dredging of the Black River at Port Huron, for the reason that other sources of infection have not been eliminated, and moreover it is my opinion as a bacteriologist and epidemiologist that under the conditions as described typhoid bacilli could not travel from the Black River at Port Huron to Detroit in sufficient numbers and in a sufficiently virulent condition so that they would be capable of causing an outbreak of typhoid fever in the latter place."

Professor W. P. Mason, testifying about his acquaintance with the Detroit epidemic stated:

"I am acquainted with it to the extent that I have had information appertaining thereto given me by Professor Williams, who has testified in this case. He gave it to me at the time that he was collecting it. I talked the matter over with him and it seemed to me that there might be some doubt with reference to the connection between typhoid fever in Detroit and the dredging of the Black River." (6948.)

The defendants contend that in consideration of the facts above enumerated in the testimony, the evidence offered by Mr. Williams as well as the testimony of the Port Huron doctors, does not justify the conclusion that the Detroit epidemic was due to an infection coming from the dredged material in the Black River at Port Huron. Considering the fact that Mr. Williams had no personal knowledge of any typhoid existing in Port Huron, or that the dejecta of persons sick with typhoid fever was deposited in the Black River, and considering the

fact that this epidemic occurred in 1892 and he did not enter upon the investigation until 1895; considering the facts that infection from local causes, such as contaminated milk or the many sources of infection not only within the city limits of Detroit but existing upon the St. Clair River and at points near at hand has not been satisfactorily eliminated, and considering the quiescent condition of Lake St. Clair and the sedimentation taking place there at all times,—taking into consideration all these facts, the conclusion that the typhoid condition in Detroit was due to the dredging of the Black River at Port Huron is not justified and has not been established by credible evidence, and the conclusions drawn by the witnesses who have accepted this so-called Detroit epidemic as an example of infection being carried a long distance, or as an example where the bed of a river contains infection, has no justification based upon established fact.

The facts herewith presented may carry conviction sufficient to satisfy the judgment of Mr. Williams, but when the conclusions of Mr. Williams in regard to the transmission of infection based upon this so-called Detroit epidemic are used for purposes such as they are in this lawsuit, they must be based upon stronger evidence than he has presented to justify his conclusions being accepted. And the defendants in this case contend that the evidence is insufficient, unreliable, speculative and theoretical, and too indefinite to justify the conclusion that the typhoid conditions existing in Detroit in 1902 have been established as being due to the dredging of the Black River at Port Huron, a distance of fifty-seven miles away.

Washington Epidemic.

The Washington epidemic, so-called and denominated in this case, found its sponsor in Professor William T. Sedgwick. After he had finished his testimony, on May 25, 1903, he subsequently reappeared on the stand and reported that in the interval between May 25, 1903 and June 27, 1903, he had discov-

ered and brought to light what is referred to in this litigation as the Washington epidemic. The facts upon which this epidemic is based by Professor Sedgwick, wherein he alleges that the typhoid conditions in Washington, District of Columbia, were due to Cumberland, Maryland, a distance of 175 miles away, are set forth in his testimony as follows:

"Q. What other stream is it that you have investigated and found the waters polluted?

"A. At that time I recalled indistinctly and not with sufficient knowledge to enable me to testify in regard to it, the facts relating to the pollution of the Potomac River and the effect of this pollution upon the typhoid fever conditions in the City of Washington, District of Columbia. Since that time I have visited Washington and made a careful examination of the typhoid fever statistics on file in the office of the Department of Health, and in particular, have inquired into a very serious and extensive infection of the river which took place at Cumberland, Maryland, in 1890. I have also visited Cumberland and have made inquiries from some of the physicians and I have secured by correspondence from one of the physicians who at the time of the epidemic wrote about it and has been much quoted in regard to it, and I find that in December, 1889, and more particularly in January, February, March and April, 1890, there was in the town, or city, I suppose it is—in the City of Cumberland a very extensive epidemic of typhoid fever, the effect of which was at the time, by a competent investigator, asserted to be plainly discoverable in an increase of the typhoid fever cases in Washington. I have recently reviewed the records in Washington and obtained from physicians on the spot at the time, in Cumberland, the facts so far as they could give them to me in that city; and *I believe that this epidemic and its consequences constitute one of the most important examples on record of the transmission of typhoid fever germs over long distances.*

"Q. Professor, did you ascertain that there was an epi-

demic of typhoid in 1889 and 1890 in the City of Cumberland, Maryland?

"A. I did.

"Q. Do you know about how many cases there were?

"A. There appear to have been in January, 1890, 18 deaths; in February, 27 deaths; in March, 39 deaths; in April, 8 deaths; in May, 5 deaths; and there was also one death in December, but this was that of an imported case.

"Q. In 1889 or 1890?

"A. In December, 1889.

"Q. And the other months, were they in 1889 or 1890?

"A. In 1890, those that I gave you. That is to say, by some the epidemic was thought to have begun in December, 1889, but the deaths began, properly speaking, in January, 1890. There were, therefore, all told, in the epidemic in Cumberland, 98 deaths from typhoid fever, and although it has been repeatedly stated in sanitary discussions and pamphlets relating to the water supply of Washington that there were 485 reported cases of typhoid fever in Cumberland at this time, and in this epidemic, the number of deaths indicates that there must have been actually nearly double that amount. An effect of this epidemic appears to have become marked in Washington in March, 1890, when the total number of deaths from typhoid fever was 19, and to have extended through August, the number of deaths per month having been:

March	19
April	11
May	13
June	33
July	36
August	28

and after August no effect of the epidemic can be traced in the deaths from typhoid fever in Washington.

"This case is a particularly interesting one and has been repeatedly referred to in public meetings and conferences and hearings before Congressional and other committees and the

like, in Washington, but has not hitherto found its way to any considerable extent into the books upon the subject. I regard it, however, as perhaps on the whole, as I have already intimated, *a most instructive example of the transmission of typhoid germs in a polluted stream over a long distance*, because Cumberland is about 175 miles from Washington by the river, and because the river is of such a character as to offer a good example of a *stream neither very swift nor very slow*, but having occasional areas of what might be called slack water; these succeeded by steeper portions, and therefore affordinggood opportunities for a certain amount of so-called self-purification en route.

"The epidemic moreover in Cumberland, having been a very extensive one, must have afforded a heavy infection of the stream, although it is a fact that at that time the City of Cumberland was not at all thoroughly sewered. It is, however, peculiarly arranged with respect to the water courses flowing past or through it. It is at the junction of that portion of the river which comes down from the Allegheny mountains and another portion which comes from the West Virginia Hills, and in 1890 there was (and there still is) a large number of privies overhanging the streams, which consist of the Potomac on the South and two small runs emptying into the Potomac near the intake of the waterworks, and a creek known as Will Creek. The two runs and the creek receive directly a large amount of fecal matter from the privies referred to, and so striking was this arrangement that Dr. Kober who made the first investigation of the epidemic, published a plate showing these unsanitary conditions, and this plate has been repeatedly copied.

"One other fact of great importance I think should be mentioned. Between October 4, 1889, and March 18, 1890, the sedimentation basin in Washington and the distributing reservoir also appear to have been out of service so that during this period the water of the Potomac delivered to the citizens of Washington without purification of any kind, a fact which no doubt added to the severity of the outbreak in Washington.

"The excess of typhoid deaths—Washington has long had an excessive death rate from typhoid fever. This has been repeatedly attributed in part by competent experts to the use in that city of the Potomac River water for drinking purposes; but during and from March, 1890, through August of the same year, this excess reached extraordinary proportions; so much so that if the typhoid deaths in these months are compared with the average monthly typhoid mortality for the five years previous to 1890, and for the five years after 1890, it appears that this excess amounted to about 100 per cent. That is to say, in addition to the ordinarily excessive typhoid of Washington, there was apparently, owing to this epidemic in Cumberland, Maryland, a further excess of about 100 per cent. So clear was this connection regarded or held to be by local authorities, that when a case of Asiatic cholera was reported to have appeared in Cumberland, Maryland, in 1894, grave anxiety was felt by these experts in Washington. Fortunately, however, the case proved to be something else than Asiatic cholera.

"The question will naturally be asked, how long does it take for water to flow from Cumberland to Washington, and this time has been variously estimated; but is given by Captain Gaillard of the U. S. Engineers, in Senate Document. No. 94, 55th Congress, 2nd Session, as from *four* to *seven* days from Cumberland to the intake, and by one of the officials of the U. S. Geological Survey as from *two* to *four* days.

"It is interesting to note in connection with the epidemic in Washington in 1890, which followed that in Cumberland, Maryland, in the same year that the excess of deaths of typhoid fever in Washington is not clearly marked until about two months after the outbreak in Cumberland. That is to say, while there were eighteen deaths in Cumberland in January, 1890, no marked excess appears in Washington until March. Furthermore, while the epidemic in Cumberland ended in May, that in Washington was continued vigorously during July, and even to some extent during August. Whether this delay in the instance of deaths in Washington is or is not due to the temporary

deposit of the germs in the bed of the stream from which they were afterwards returned from the flowing water and delivered in Washington, it is impossible to say positively, *but it is difficult to resist the feeling that this may have been the case.* It is certainly a remarkable and interesting fact. We know, to be sure, that persons who have had typhoid fever continue, even after recovering, often for considerable periods, to discharge germs from the body, and it may have been that a part at least of the tardier appearance of the disease in Washington and its continuance after the epidemic in Cumberland had ceased, was due to this cause; but it may also have been due to the thorough infection of the river—of the bed of the stream, which was not not entirely washed out for some time after the epidemic was over, in part also, the later appearance is also undoubtedly due to the passage of the water through the settling basin and distributing reservoir which were in operation after March 18th.

The population of Cumberland at that time is said to have been twelve thousand.

"Q. Did they have at that time (1890) a system of waterworks in Cumberland?

"A. Yes, sir. And the epidemic in Cumberland is supposed to have been caused, and *in* my judgment was caused by an infection of their own water supply by a case of typhoid fever happening just above the intake of their waterworks, which was placed in a very objectionable position in the Potomac River.

The number of deaths in Washington during this epidemic was 140 during the period of six months.

"Q. Do you know how the distance from Cumberland to Washington by river compares with the length of the River Thames in the United Kingdom?

"A. The Thames is 209 miles long, and is, I believe, the longest river in the United Kingdom, and this epidemic seems to confirm in a very remarkable way that statement of the Rivers Pollution Commission of Great Britain, to which I have referred in my previous testimony, where they said that *there*

was no river in the world that was long enough to purify itself of any sewage introduced into it even at its source.

"Q. Now, from your knowledge of the situation, and of the conditions that prevailed in 1889 and 1890, in the City of Cumberland, Maryland, and the City of Washington, the conditions of the Potomac River and the water supply of the two towns, of the sewage and human defecation of the stream of the Potomac River, I will get you to state whether or not in your judgment, the epidemic of typhoid fever in 1889 and 1890 in the City of Washington was caused by the placing of sewage infected with typhoid bacilli in the waters of the Potomac River at the City of Cumberland, Maryland?

"A. *I should hardly call the excess of typhoid fever in Washington in 1890 an epidemic, although that term might perhaps very well be applied to it. It was rather an extraordinary and unusual excess of typhoid fever, and, in my judgment, this excess was and is directly traceable to the great epidemic of typhoid fever occurring shortly before, and during a portion of the same period in the City of Cumberland, Maryland—germs from that epidemic having apparently passed down the river into the water supply of the City of Washington alive and virulent. Of course there must have been a considerable removal of germs en route, else the outbreak in Washington would have been far more severe.*" (2758-66.)

These facts, detailed on direct examination, with the opinion of Professor Sedgwick above presented are all the facts that he offered in evidence in regard to the so-called Washington epidemic. There is but one objection which the defendants find to Professor Sedgwick's conclusion, and that is that the facts in this case do not justify it. His answers on cross-examination shed a great deal of light upon the limited knowledge that he possessed in connection with the conclusion which he drew from the facts as he related them in his direct testimony. His cross-examination is in part as follows:

"Q. You are now acting for and in behalf of the State of

Missouri in an *advisory capacity in this lawsuit as an expert?*

"A. *I understand that I am, yes, sir.*

"Q. What other experts have studied the epidemic about Cumberland and the consequent increase of typhoid at Washington in 1890 and 1891?

"A. So far as I know, no one has studied it thoroughly excepting Dr. Kober, and, if I may be permitted to say so, myself.

"Q. What other expert had grave apprehensions as to Asiatic cholera when it was discovered that there was a case of Asiatic cholera in Cumberland?

"A. My authority for the statement which I have made in that connection is Dr. J. J. Kinyoun, connected until recently with the U. S. Marine Hospital Service, and is found in a discussion by Dr. Kinyoun of the question of water supply for the District of Columbia published in Document 183, Fifty-fifth Congress, Second Session, page 25.

"Q. What other experts, now, had grave anxiety about Asiatic cholera than the one you have named?

"A. He is the only one that I know of that had such anxiety, but, as I know that he was associated with other sanitarians of note, I have no doubt that the matter was talked over by them at the time.

"Q. Did you talk with Dr. Kinyoun yourself in this visit to Washington?

"A. No, sir; I did not.

"Q. Your information as to his grave anxiety arises from reading something that he got in print?

"A. It does.

"Q. Then because he did that you infer that other sanitarians had like grave anxiety with reference to it?

"A. I do.

"Q. Now, before what Committee of Congress was this epidemic in Cumberland discussed?

"A. It was not discussed, so far as I knew, before any committee.

"Q. By what committee was it investigated?

"A. Nor was it investigated.

"Q. Now, whether any committee of Congress actually investigated the epidemic in Cumberland you are not prepared to state?

"A. I am not prepared to state.

"Q. Now, from what source did you obtain that information of 485 cases in Cumberland?

"A. That rests both in Dr. Kober's reports and in my own case upon the authority of Dr. W. W. Wiley of Cumberland. The health records of Cumberland are exceedingly defective, and I am dependent, as Dr. Kober was, upon Dr. Wiley, the local physician.

"Q. What is the area of the fall of the Potomac?

"A. I have no personal knowledge of this, but referring to Colonel Miller, of the United States Engineers, the drainage area above the intake figures 11,043 square miles.

"Q. 44½ of population to the square mile?

"A. Yes, estimated for 1900.

"Q. Now, in 1889 was typhoid fever in any one of these towns save Cumberland?

"A. Not so far as I have been able to learn.

"Q. You have not heard of any?

"A. I have inquired and have not learned of any.

"Q. What kind of inquiries did you make about it?

"A. In Washington, talking with health officials who are fairly familiar with the condition of watersheds, and in Cumberland with physicians. * * *

"Q. With what other persons have you talked upon the subject?

"A. No one else in Washington, except some of the people in the office whom I didn't know, but in Cumberland, with the doctors that I referred to.

"Q. You arrived there (at Cumberland) on some morning train and left on some noon train?

"A. The other way around. I arrived at noon and left at night.

"Q. Do you know whether there was typhoid fever in any of the towns on any of the tributaries above Cumberland, on the Potomac, at that time?

"A. Not so far as I could learn.

"Q. You have not heard of any?

"A. I have not heard of any.

"Q. Was there any typhoid in this period and prior to it in the valley of that river (Monocacey River)?

"A. I don't know of any, but I have no doubt there was some few cases.

"Q. Having learned from reports and conference that there was considerable typhoid fever at Cumberland at one time and subsequently a remarkable increase of typhoid fever in Washington, and not knowing as to typhoid fever at any place else, you conclude that the typhoid fever in Washington is attributable to Cumberland?

"A. I do.

"Q. Your entire knowledge of it has been gained and acquired since about the 1st of June and since that time?

"A. My DEFINITE knowledge of it has been acquired since that time. * * *

"Q. Can you tell me why the cases in January, 1890, in Cumberland didn't show any effect, if they ever had any, in Washington in February?

"A. I cannot. There was a slight increase in January in Washington, but it was so slight that I didn't feel it fair to attribute it with any strong presumption or probability to the cases of Cumberland. * * * At the same time it is entirely possible that this slight excess in January was due to the cases in Cumberland.

"Q. At what time is the Potomac River in flood at Cumberland?

"A. I have not learned with any great degree of accuracy of the flood periods of the Potomac, or at least beyond the statement of Captain Gaillard, that its flow is very marked, varying from a minimum at Great Falls of about 1,063 feet per

second, to between 400,000 and 500,000 during the great freshet in June, 1889. * * *

"Q. And do you know when there was another flood after that?

"I do not.

"Or in the winter of 1899 and '90?

"A. I do not; but, of course, it was fair to suppose that with the breaking up of the snow on the Virginia mountains and the Allegheny there must have been the usual spring floods. *I have not undertaken to connect closely the typhoid in Washington with the typhoid in Cumberland, believing that no such close connection could be traced to that, but that only a broad and general connection was discoverable.*

"Q. Do you believe that the typhoid fever which occurred in Cumberland in January, 1890, contributed to the typhoid fever in Washington in March of the same year?

"A. I certainly do.

"Q. On what theory?

"A. For the reason that we have good reason to believe that germs of that disease were deposited in the Potomac water at Cumberland. We know that this water travels down the river, and is, in part at least, used for drinking purposes by the people of Washington. We find an otherwise inexplicable excess in typhoid fever in Washington at a time following when such increase would reasonably be unexpected.

"Q. All the water in the Potomac River at Cumberland had flowed past the City of Washington in the Potomac long before this epidemic or increase of typhoid fever in Washington, that is to say, the water infected, if it was infected, by typhoid fever in January at Cumberland, had flowed past the City of Washington, a very considerable time before, allowing for the period of incubation, had it not?

"A. I should suppose that it must have, in a large part, perhaps entirely. * * * I think we should bear in mind that in January it is possible that the stream was tightly frozen

and that sedimentation took place to an unusual extent for a time, so-called self-purification going on.

"Q. Is the Potomac River ever frozen between Cumberland and Washington?

"A. I have no personal knowledge of it, but I don't see how it can be otherwise. * * *

"Q. Of course there is no way of determining as an actual fact whether any typhoid fever germs were deposited in any of the sluggish places in the Potomac River?

"A. No, sir.

"Q. Nor whether they were washed out so as to contribute to the typhoid fever in Washington in March?

"A. No, sir. We can only infer from the end results what may have happened.

"Q. And the belief that typhoid fever in Cumberland was the cause of typhoid fever is based upon the theory that typhoid fever germs live in water and are transported by water and retain their virulence?

"A. That certainly is the theory sir."

On further cross-examination the witness stated:

"Q. What percentage of the sewage of Cumberland found its way into the Potomac River?

"A. That would be impossible for me to answer, or for any one to answer. I have no information as to the number of typhoid cases or deaths that occurred in houses where the outhouses overhung the stream, nor as to the number of typhoid deaths that were in houses that used private vaults.

"Q. Have you any information as to whether the fecal discharge from typhoid patients in Cumberland was treated by the application of any antiseptic?

"A. I have not.

"Q. If it should appear that under the direction of the doctors such antiseptic precautions had been taken, would not you deem it necessary to ascertain that fact in order to draw a correct conclusion as to the effect of the sewage of Cumberland upon the Potomac River?

"A. No, sir, I should not, broadly speaking, because it is well known that any such general order for disinfection or any such practice of disinfection is always only partially obeyed, and I should rather believe that the moderate character of the excess in Washington, which I have hesitated to call an epidemic, was, in part due very likely to some such disinfection.

"Q. Do you know whether the out-houses that received the excreta of the typhoid patients were emptied into the Potomac or not?

"A. I do not.

"Q. Did you make any inquiries from anybody at Harper's Ferry who would be most likely to know the (typhoid) conditions there?

"A. I did not.

"Q. Did you make any inquiries especially as to whether there was any typhoid fever at Harper's Ferry or not from any one that lived at Harper's Ferry?

"A. I did not * * * I made no inquiries except of the health authorities in Washington and Cumberland.

"Q. Do you know whether he (the health officer) made any investigations at Harper's Ferry to ascertain the condition that existed there at this time?

"A. I do not.

"Q. And whether typhoid fever existed at Harper's Ferry at this time or not, you have no knowledge?

"A. I have no personal knowledge.

"Q. Do you know how many cases of typhoid existed between Cumberland and Washington along the watershed of the Potomac?

"A. I do not.

"Q. Did you make any investigation to ascertain the number?

"A. No, sir.

"Q. And the reason that you didn't do it was because you did not deem it essential?

"A. That is it exactly.

"Q. And whether there were a great number of typhoids there or not you are not prepared to say are you?

"A. I am not prepared to say positively, but if there had been I am sure that I should have heard of it.

"Q. If you made no effort to ascertain it, how would you have heard it?

"A. Because Dr. Kober, who investigated the thing at the time, would have been, in my judgment, sure to mention the fact, as he is a careful man.

"Q. Then the fact that no one mentioned it to you is the only ground that you have for believing that there was no considerable amount of typhoid fever within that stretch of 170 miles?

"A. Not exactly that no one mentioned it to me, but that no record of it appears in the report of the investigation at that time.

"Q. You made no effort to ascertain that fact, did you?

"A. No, I did not. I didn't deem it necessary." (2767-2789.)

If there was anything in addition to the cross-examination of Professor Sedgwick which developed that he had no knowledge of the number of typhoid fever cases existing between Cumberland and Washington, or upon the watershed of the Potomac above Washington, immediately prior to the outbreak of typhoid fever in Washington, and to show how carelessly he investigated the facts upon which he was willing to predicate his judgment, and also to demonstrate how reckless he was in making statements to the effect that if there had been typhoid fever above Washington and between Cumberland and Washington that he would be sure to have heard of it, reference is made to the testimony of Dr. W. W. Wiley, a witness called by complainants who testified in this case, in his testimony on page 2866, in which he stated:

"I communicated with a doctor at Hancock, that is a place about sixty miles below Cumberland, and soon after we had our epidemic in Cumberland they began to have cases at Hancock,

but I never heard the number, but they had quite a number of cases at Hancock and accused us of communicating it to them."

Mr. William C. Woodward, health officer of the District of Columbia, called as a witness for complainant, testified as follows:

"Q. Do you regard the water of the Potomac as the sole cause of the typhoid fever in the City of Washington?

"A. No, sir. * * We have of course a direct infection of one patient from another, a great number of such persons who are infected through milk, a certain number who are infected through oysters and vegetables eaten raw, and persons visiting here from other cities and persons returning from summer resorts who are residents here." (2883.)

It is a remarkable contrast between Professor Sedgwick's statement on direct examination, which is: "In my judgment this excess was and is directly traceable to the great epidemic of typhoid fever occurring shortly before and during a portion of the same period in the City of Cumberland, Maryland," and the statement upon cross-examination in which he states: "I have not undertaken to connect closely the typhoid in Washington with the typhoid in Cumberland, believing that no such close connection could be traced to that, but that only a broad and general connection was discoverable."

Counsel for defendants are at a loss to understand what the learned professor means by this seeming contradiction. Is the cause of an epidemic such that a close connection cannot be traced to the cause, but that only a broad and general connection is discoverable?

If such be the case, how is it that "this epidemic and its consequences contribute one of the most important examples on record of the transmission of typhoid fever germs for long distances"?

If this epidemic is established as being due to Cumberland by Professor Sedgwick without any knowledge or information as to typhoid conditions which obtained between Cumberland and

Washington upon the Potomac watershed, it introduces a new element that is *sui generis* in connection with the question of the transmission of infection.

We find that the rate of flow between Cumberland and Washington is from two to seven days, and the typhoid rate in Cumberland compared with that in Washington, with an interval of two to seven days intervening, shows that in March there were thirty-nine deaths in Cumberland and nineteen deaths in Washington; in April eight deaths in Cumberland, eleven deaths in Washington; in May five deaths in Cumberland, thirteen deaths in Washington; in June, no deaths in Cumberland and thirty-three deaths in Washington; in July no deaths in Cumberland and thirty-six deaths in Washington, and in August no deaths in Cumberland and twenty-eight deaths in Washington.

The relationship existing betwen typhoid fever existing in Washington and that in Cumberland, based upon the statistics alone, as introduced by Professor Sedgwick, does not permit of any connection being made between Washington and Cumberland.

The defendants contend that as to the so-called Washington epidemic, so far as it is traced to infection due to Cumberland, Maryland, by Professor Sedgwick, the evidence fails altogether to show any connection, and to employ this evidence by way of illustration that typhoid germs will travel from Chicago to St. Louis is as unjustified an assumption as that based upon the so-called Detroit epidemic. It is difficulty to understand how so learned a man as Professor Sedgwick could commit himself to such fallacious reasoning as he has done in connection with this so-called Washington epidemic. But the evidence plainly shows that the conclusions of Professor Sedgwick, based upon the facts connected with the Washington epidemic are fallacious, erroneous and unjustifiable.

Covington.

Several of complainant's witnesses, among whom was Professor Sedgwick, in order to establish that a typhoid germ will

live in the sediment of a stream for a long period of time, have cited as an example conditions that obtain at Covington, Kentucky. He states in his testimony on page 2238 as follows:

"Q. Do you know of any instance where settling basins holding suspected water for longer periods than this one at Lawrence have failed to protect the people using such water from typhoid fever, and if so what are they?

"A. There are well known cases: Covington, Kentucky, and New Albany, Indiana, deserve mention. At Covington, Kentucky, the water of the Ohio River, more or less polluted on the stream above, is kept at times as long as thirty-two days, and yet Covington suffers severely from typhoid fever, apparently due to infected water. At New Albany, Indiana, on the same stream, the storage is about a month in the sedimentation basin, as in the case of Covington, but typhoid fever was high in New Albany, showing that the storage for a period even as long as a month cannot be depended upon to entirely remove the typhoid germs."

A complete refutation of Professor Sedgwick's assumption in regard to the typhoid condition in Covington is found in the testimony of Mr. John W. Hill, which is as follows:

"Q. Are you acquainted with the settling basins in the City of Covington, Kentucky?

"A. I am.

"Q. What acquaintance have you with those settling basins?

"A. I was familiar with the construction at the time they were being built by reason of temporary employment by the contractors and by reason of further connection with the suit brought by the contractors, Casparius & Company, against the trustees of the Covington reservoir, for alleged extras in connection with the work of construction. Later on I renewed my acquaintance with these works in connection with the plans for the improvement of the water supply of Cincinnati at which time samples were taken from the Covington reservoirs to determine how much, if any, purification was going on by reason

of long sedimentation. At that time the two distributing basins carried about thirty days' supply, that is to say, when operated upon the continuous sedimentation plan it would take about thirty days to empty the reservoirs, or rather to discharge the original volume of water and have it replaced with unsedimented water pumped from the Ohio River. The result of those investigations is recorded in the report of the Engineering Commission of the City of Cincinnati, published March, 1896. And as I now recall upon some occasions the bacterial tests of the water in Covington reservoirs compared with the test of the water in the river flowing past the intake of the Covington Pumping Station, revealed at times a reduction of the bacteria by as much as 97 per cent. I think the average of the tests that were made (perhaps a dozen or more during the month of January, February and March, 1896) indicated more than 90 per cent. bacterial reduction by simple sedimentation for 30 days.

"Q. Where the settling basin such as existed at Covington, Kentucky, held a sufficient amount of water to supply the city of Covington for a period of thirty days and as the water was taken out for domestic uses is immediately supplied from the open river, and typhoid fever should prevail among the people of Covington using such water, what is your opinion as to whether such a condition of typhoid fever existing in Covington, Kentucky, justifies the assumption that because the basins hold a supply for thirty days, that the typhoid bacillus will live in that water for such a period?

"A. I do not think that it does justify such an assumption. The circumstances with reference to Covington and the sister City of Newport, which also has a large sedimentation basin and the City of Cincinnati are these: A large part of the population of each of the two smaller cities in Kentucky do business or are otherwise engaged daily in Cincinnati, and from investigations of the typhoid fever rates of the three cities from 1890 to 1896, there is satisfactory evidence to my mind that the larger part of the typhoid in Covington and Newport is charge-

able to the Cincinnati water, that is, to water that was used by the people who were either attending school or looking after business or doing their shopping in the larger city, and a fair test of the influence of thirty days' sedimentation on the Ohio River water is not made in the daily experience of Covington because of this constant change of population from Covington to Cincinnati every day excepting Sunday. Notwithstanding the conditions which reflect upon the action of the Covington reservoir, the typhoid fever rates are much lower in Covington than they are in Cincinnati.

"Q. Have you the typhoid rate of Covington and Cincinnati?

"A. I have for the years 1890 to 1896. Quoting the rates of Cincinnati for the years 1890 to 1896, inclusive, by years they run as follows per 100,000 of population.

1890	67
1891	62
1892	40
1893	43
1894	50
1895	36
1896	48
Average	49.4

For Covington for the same years and upon the same basis:

1890	43
1891	45
1892	40
1893	27
1894	42
1895	27
1896	32
Average	36.6

With the exception of the year 1892, the typhoid fever rates per 100,000 population were always lower in the City of Covington than in the City of Cincinnati, both taking water from the Ohio River.

"Q. What was the character of the water supply of Cincinnati during this time?

"A. In general terms it was bad because at that time and now no attempt had been made at improvement of the quality of the water after it was taken from the river, excepting such as may take place in passing through the Eden Park reservoir, which holds ordinarily about one and one-half days' supply.

"Q. From what you know of the typhoid conditions existing in Covington, Kentucky, what is your opinion as to the validity of attributing the typhoid conditions to the water from the reservoir of the city of Covington?

"A. Having investigated the typhoid fever rates at Covington, it never occurred to me that it was chargeable to the local water, but that it was chargeable to the very considerable daily consumption of unsedimented water that the people of Covington drank, or some of them drank, in the City of Cincinnati daily. There are other sources of typhoid infection that must be taken into consideration, namely, the drinking of water during travel of the members of an organized community, and importing cases which will be charged to the city of residence. I do not believe that all typhoid in Covington was due to the Cincinnati water, but I do believe a large portion of it was. In Covington, also, there is considerable drinking water used from old-fashioned dug wells, and it is possible that some of the typhoid may be chargeable to that cause.

"Q. What effect do wells have upon the public health as regards typhoid in large cities?

"A. It is, I believe, a common opinion of sanitarians to-day, and it is certainly my opinion, that an open well is not a safe source of drinking water in an old and well built up urban community, by reason of the fact that soil in due time will become polluted with the waste from privy vaults and cesspools and that pathogenic bacteria and perhaps other objectionable matter from such cesspools and vaults may by the ordinary means find a way into the well and render such water unfit for drinking purposes." (7533-7536.)

Pittsburg Epidemic.

The typhoid conditions in Pittsburg at the time that the same were investigated by Professor Sedgwick were attributed by him to the sewage coming from Oil City, 103 miles above Pittsburg, on the Allegheny River. The defendants in this case do not contend that infection could not come from Oil City, Pennsylvania, to Pittsburg, since the evidence introduced in this case by Professor Sedgwick shows that the time of flow of the Allegheny River from Oil City to Pittsburg was less than two days, and at times a matter of a few hours; but defendants do contend that the evidence submitted by Professor Sedgwick upon which he bases his judgment is not sufficient to warrant his conclusions. These facts appear in Professor Sedgwick's testimony, on page 2208, in which he says:

"In 1898, I think it was, I made a special study of typhoid fever in Pittsburg. Acting on advice of one of the most eminent engineers of the time, Pittsburg introduced a water supply a number of years ago—twenty or thirty years ago, drawn from the Allegheny River, mainly, and partly from the Monongahela. Now, the Allegheny is a swift stream, with only remote pollutions. There is no near pollution that amounts to much, if anything, but the remote pollution from Oil City, etc., and as a result of the careful study of that epidemic, prolonged for some weeks—not of that epidemic, but of the study of cases of typhoid fever in Pittsburg, it resulted in the recommending of the filtration plant for the City of Pittsburg, for the reason that, in my judgment, infectious materials might be brought to cities which had no filtration plants, from points as distant as Oil City, or even more remote,—113 miles or more. I reported that in 1898, and am on record as having said that in 1898."

On cross-examination these questions were asked of Professor Sedgwick:

"Q. When you made an examination of the water supply at Pittsburg, did you go to Oil City?

"A. No, sir. Yes, I did; but not further than to pass through.

"Q. You made no examination as to the conditions in Oil City from which, or to which, you thought it probable that typhoid in Pittsburg was to be attributed?

"A. I made no personal examination of conditions in Oil City.

"Q. Do you know whether there was in Oil City an ordinance of the city requiring that all dejecta and urine of typhoid people should be destroyed?

"A. I do not. I do not now recall that there was any such ordinance.

"Q. Do you know whether there was any such—

"A. May I fix that answer? I do not now recall that I had any knowledge of any such ordinance.

"Q. When you made the examination in Pittsburg, was there then an epidemic of typhoid fever in Pittsburg?

"A. There was no great epidemic; there was a considerable number of cases, and typhoid fever in Pittsburg had long been high, so that one might say there was a continuous epidemic, but there was no such great increase in the number of cases over the ordinary as there was, for example, in Lowell.

"Q. Had there been previous to that a very great increase of typhoid in Oil City?

"A. I don't remember.

"Q. Do you know whether previous to that and during the continuance of the high rate of typhoid fever in Pittsburg, there was an excess of typhoid fever in Oil City?

"A. I cannot remember.

"Q. In reporting upon the condition of affairs at Pittsburg, and the remedy to be applied, did you exclude all considerations except the existence of the Allegheny River and the flourishing towns above Pittsburg?

"A. I did.

"Q. And, without knowing whether there was typhoid fever in any one of those towns, or an excessive rate of typhoid fever in any one of those towns, you ascribe the typhoid fever in Pittsburg to the infection of the Allegheny River from towns above it?

"A. I do not remember whether there was any above or not; whether I based my conclusion upon that partly or not; but in any case, even supposing there had been an excess up there, I should have come to the same conclusion, because they were pouring regularly a certain amount of sewage into the stream.

"Q. Then all this is necessary to make the waters of a running stream unsafe, as to typhoid fever, is the fact that the sewage of populous places above is poured into the river?

"A. Broadly speaking, yes. In taking this thing as an ordinary proposition, and taking the question as a broad one, we may always assume that sooner or later there will be in the sewage of a populous city or town, germs of typhoid fever." (2281-2.)

In comparing conditions which exist between Oil City and Pittsburg, wherein the Allegheny becomes the vehicle for the transmission of disease germs from Oil City to Pittsburg, a distance of 113 miles, with conditions as they obtain along the Illinois River from Chicago to St. Louis, Professor Jordan's testimony upon this question will show how futile is the effort to draw comparisons between conditions at Pittsburg and those existing at St. Louis, in order to show a comparison of the two water courses, the Allegheny and the Illinois.

Professor Jordan's testimony on this point is as follows:

"Q. How do the physical conditions of the Illinois River compare with the other rivers in the country for the purpose of purification?

"A. As compared with rivers of high velocity, the conditions for purification in the Illinois River, as already set forth, are especially favorable. The sluggish current which permits a sufficient lapse of time for the death of pathogenic bacteria, and which also facilitates and furthers sedimentation, constitutes an element wholly favorable to self-purification.

"As compared with the Mississippi River, where the current is swifter, and especially as compared with the Missouri River,

the opportunities for purification in the Illinois River are quite superior.

"Any factors that tend to increase the opportunities for sedimentation and that tend to delay the progress of pathogenic microbes down stream further the progress of purification. In these respects the conditions in the Illinois River are greatly superior to the conditions in the Mississippi and Missouri Rivers. As compared with some other streams in this country that have been studied with a view to the opportunities for self-purification, the Illinois River is well adapted for self-purification.

"I find in the report of the Filtration Commission of Pittsburg, Pennsylvania, published in January, 1899, in a report upon the sources of typhoid fever in Pittsburg, by my friend, Professor W. T. Sedgwick, who has testified in this case, the following statement: I will quote what he says about the Allegheny River under the heading, "The Allegheny River a rapid stream, with little or no opportunity for self-purification," page 18.

"'Any one who will take the trouble to follow the Allegheny River from Oil City to Pittsburg merely as a passenger on the Allegheny Valley Railway, particularly if he is familiar with the streams in the less mountainous parts of the country, cannot fail to be impressed immediately with the fact that we have in the Allegheny River a peculiar and characteristic stream. Owing no doubt to the character of the rock through which it has cut its way, it exhibits a very regular, deep line from Oil City to Pittsburg. There is no mill dam of any consequence between these two cities, and the river is, therefore, narrow, as is not frequently the case with rivers in New England and elsewhere in which a series of mill ponds containing slowly moving water, and in which the elements of sluggishness and quiescence are, except in periods of freshets, a chief characteristic, but rather, even at low water, like a brawling brook, making its way rapidly over a stony bed in which are very few pools or other quiet places adapted to purification, in which there is little or no evidence

of effective sedimentation, as is proved by the absence of mud banks, sand bars and the like, but exhibiting everywhere stones polished by the swiftly flowing stream and without effective lodging places for mud or bacteria. An estimate roughly made of the rate of flow shows to the traveler a probable velocity in most places of at least a foot per second, and often much more than this, even at low water. With high water the velocity must obviously be much more rapid. Clearly, the two fundamental elements looking towards self-purification in rivers are here wanting, namely, time and quiescence. The velocity of the river and the character of its bed are such that foul water introduced, for example, at Oil City or nearer points may, and indeed must, arrive at Pittsburg within a very few hours. Fortunately, however, we do not have to rely on the rough observations of passing travelers, but are in possession of authoritative calculations. According to results obtained from the United States Engineer's office at Pittsburg, the average velocity of the Allegheny River, even during low water, is from one to two miles per hour. During high water it is from seven to eight miles per hour, and on the average of about three and one-half miles. This means that infectious materials poured in at Oil City or nearer points may arrive at Brilliant within fifteen hours, or even at low water must arrive within a few days.

"'It has just been shown that in the bed of the Allegheny River very little or no opportunity occurs for purification en route by the usual processes which are more or less effected in rivers.'"

"I would say that I entirely agree with Professor Sedgwick that the Allegheny River as he describes it affords few opportunities for the process of self-purification, and that I agree in his conclusions as to the rapid march of infectious material under such conditions. The conditions in the Illinois River, however, as hereinbefore set forth, are very different from those prevailing in the Allegheny River. In the Illinois River, as in other sluggish streams, those elements that favor self-purification in rivers, namely, time and quiescence, are present in force.

There are few rivers in the United States with which I am familiar where the factors making for self-purification are so potent as they are in the case of the Illinois River. Both the Mississippi and Missouri Rivers are less favorable in this respect." (6169-6172.)

If the description of the Allegheny River, a stream having its source on the western slope of the Alleghenies, flowing westward, is compared with Professor Sedgwick's description of the Potomac from Cumberland to Washington, the dissimilarity of description of two rivers almost identical—one flowing a distance of 113 miles to the west, with a time velocity of two days or less, the other flowing eastward a distance of 175 miles, with a varying time velocity of from three to five days, is very apparent.

If in the bed of the Allegheny River little or no opportunity occurs for purification en route by the usual processes which are more or less effected in rivers, why would conditions obtain in the Potomac River, a stream flowing at times with a velocity sufficient for water to pass from Cumberland to Washington in a period of two days, that would permit bacteria and pathogenic germs to remain deposited in its bed for periods of 90 to 120 days, as would have to be the case in order to trace a connection between the typhoid fever conditions existing in Washington in August with the typhoid epidemic that occurred in Cumberland during the months of January, February and March, 1890? The theory that typhoid germs are sedimented for such a period in the Potomac River and retain their virulence is a gratuitous assumption and no evidence has been offered in this case that establishes it as a fact.

Zurich, Switzerland.

Lortet's Observation.

Typhoid conditions, such as existed at Zurich, Switzerland, have been cited in the evidence in this case as an instance of typhoid fever certainly traceable to typhoid bacilli which had existed for a considerable time in sediments.

Reference to Zurich, Switzerland, by Professor Sedgwick and Mr. Fuller appears from the evidence in this case to have been confounded with Lortet's observation upon the sediment in Lake Geneva. However, the incident was offered in evidence for the purpose of illustrating the longevity of typhoid germs in the sediment of a lake and the inferences drawn from this investigation are set forth in the testimony of Professor Sedgwick and Mr. Fuller, which is here quoted in part as follows:

"Q. Did you ever know of a case or cases of typhoid fever which were certainly traceable to typhoid bacilli which had existed for any length of time in the sediment of a running stream?

"A. I mentioned in my direct evidence the well known epidemic in Zurich, Switzerland, which was regarded by those who investigated it as clearly traced to the stirring of the sediment near a broken intake pipe, and I also mentioned, further, the Detroit case, which, to the best of my judgment and belief, was conclusively traced to the stirring of sediment in the Black River near the St. Clair River. In my own personal experience I don't think that I have." (2309.)

Mr. George W. Fuller also cited this incident to illustrate the same conditions that Professor Sedgwick did, and his testimony upon the subject is, in part, as follows:

"Q. In regard to the typhoid germ living in the sediment of streams, do you know of any one that has ever discovered a typhoid germ in the sediment of a stream, a running stream?

"A. It has been found in the sediment of lakes, and we know it exists, beyond all doubt, in the sediment of running streams.

"Q. Has it ever been demonstrated by bacteriologists that typhoid germs have lived in the sediment of a running stream?

"A. It has been demonstrated that they have lived for a long time in the sediment of lakes, and I do not consider that there is any weakness in the process of reasoning by which one steps from a lake to a river, provided, of course, that each of those waters are live waters and not subject to aseptic action.

"Q. By whom has it been ascertained that the typhoid germ has been found to live in the sediment of a running stream or lake?

"A. There are observers in Switzerland who made such examinations with a positive result showing the presence of typhoid germs in the sediment of Lake Geneva; I think, also, of Lake Zurich.

"Q. How long after the germs were put into the sediment was it before they were discovered?

"A. I do not know in the case of the particular germ which they found, but they were found considerably more than a mile from the shore, off from the outlet of any sewers.

"Q. Is not the length of time that the typhoid bacillus will live in a sediment more a matter of assumption than a matter of demonstrated proof?

"A. I consider that it is a very clean cut, demonstrated fact that typhoid fever germs may, do and have continued to live in the sediment of running waters.

"Q. For what length of time?

"A. I should say for a month or more, possibly in cases for years.

"Q. Who has demonstrated that it ever lived a year?

"A. I think that the conditions existing in the moist soil in many rural places in this country where typhoid fever prevails from time to time are proof that typhoid fever germs in the presence of moisture can live for such a term. If that were not so, then there would be an elimination absolutely of typhoid fever through the rural districts of this and all other countries." (Pages 2662 and 2663.)

The foregoing testimony again serves to illustrate how ready the experts called on the part of the complainant in this case were to accept facts for the purposes of illustration, concerning which they knew but little and from which they were willing to draw far-reaching scientific conclusions. The conditions existing at Zurich, Switzerland, which complainant's witnesses, as above quoted, cited as an instance where typhoid germs had

existed for a considerable time in the sediment of a lake, together with Mr. Fuller's inference that because typhoid germs live for a long period in moist soil it naturally follows that they will live equally well in the sediment of a stream, will be discussed as one proposition, but considered separately. The question, DO TYPHOID GERMS EXIST FOR A LONG TIME IN THE SEDIMENT OF A STREAM? has been given considerable attention by the witnesses called on the part of the defendants in this case, and in that connection Mr. Fuller's comparison between conditions existing in moist soil and the sediment of a river, together with his citation, as well as that of Professor Sedgwick's in regard to Zurich, Switzerland, has received special attention.

Professor E. O. Jordan, one of the clearest headed scientists who have testified in this case—and reference to his entire testimony will show that this statement is not fulsome flattery, but well merited praise—testified upon these two propositions, in part, as follows:

"Q. What is your opinion as to whether the typhoid bacillus will live longer in the sediment of a polluted stream than it would in the water of the same stream?

"A. It is my opinion that there would be little material difference.

"Why?

"A. In the sediment of running streams the typhoid bacilli are in very much the same surroundings, so far as I can picture to myself the conditions obtaining in this sediment, that they would be in the water of such streams, except that it is fair to suppose that the organic matters on the bed of the stream in the sediment are more abundant. This latter condition would bring it about that the food substances of the saprophytic bacteria would be present in the sediment more abundantly, and that, therefore, the products of growth of these microbes would exist there also in a more concentrated form, so that, so far as typhoid bacilli would be differently affected by the conditions obtaining in the sediment, they would be exposed to the toxic products of saprophytic microbes more intensely than in the water of

the stream above this sediment. This condition would tend, if anything, to cause their death more speedily in the sediment than in the water of the same stream, although I do not believe that the difference would be very great.

"Q. Will you differentiate between the conditions that obtain in moist soil and the sediment of a running stream?

"A. In moist soil the bacilli are not exposed to the action of the toxic products of the microbes with which they are surrounded, for the reason that such soluble toxic products cannot act upon the bacilli through the intervening air space. A continuous layer of fluid would be needed for a diffusion of the soluble toxic products of these saprophytes, and unless the typhoid bacilli were in contact with these, the conditions in an ordinary damp soil would be very different from the conditions prevailing in the sediment on the bottom of a river or pond.

"Q. Does the time that the typhoid bacilli will live in moist soil furnish any criterion for its longevity in the sediment of a running stream?

"A. I do not see how it could, for the reasons just stated.

"Q. Are the two conditions comparable?

"A. They seem to me very different unless one assumes that by moist soil is meant soil saturated or covered with water, in which case the conditions would be substantially the same as these obtaining in the sediment, and the same result might be anticipated.

"Q. How long, in your judgment, will a typhoid bacillus live in a moist soil?

"A. Under such conditions as prevail where the contents of privy vaults are spread upon the surface of fields or vegetable gardens typhoid bacilli may, in my opinion, live for many months. Under these conditions there is sufficient moisture present for them to retain their vitality, and at the same time, owing to the lack of a continuous layer of fluid, any toxic products of other microbes cannot diffuse through the mass and injure the typhoid bacilli.

"Q. Would the fact that the typhoid bacillus lived several

months in moist soil justify the assumption that it would live for the same length of time in the sediment of a river?

"A. By no means.

"Q. Will you please give your reasons in full for the answer you have just given?

"A. The conditions in ordinary moist soil and in the sediment of a river differ practically, since in ordinary moist soil, if I understand what is meant by that term, there is slight opportunity for the action of the soluble toxic products of saprophytic bacteria upon the typhoid bacilli, and, as I have stated, there is reason to believe that it is the effect of these soluble products upon the typhoid bacillus in water that causes the death of the latter. The poisons of these bacteria could not influence so profoundly the longevity of the typhoid bacillus in soil.

"The experiments by Doctor Savage that I have already cited, on the disappearance of the colon bacillus from soil, indicate, however, that the typhoid bacillus will probably die out in soil, like its more hardy relative, the colon bacillus, although less speedily than in the sediment of a river or in polluted water.

"Q. Do you know of any bacteriologist since the beginning of bacteriology that has demonstrated by any experiments that germs do live in the sediment of lakes or rivers for a long period of time?

"A. I do not.

"Q. Professor, Mr. Fuller in his testimony stated that 'There were observers over in Switzerland who made such examinations with positive results showing the presence of typhoid germs in the sediment of Lake Geneva; I think, also, Lake Zurich.' Do you know anything about these observations to which Mr. Fuller referred?

"A. I know of the observations on Lake Geneva, to which I suppose, this statement refers. I have made an examination of the literature to discover something regarding the presence of typhoid germs in the sediment of Lake Zurich, but I have found nothing that bears directly on this point.

"Q. Will you please state the facts and circumstances as you know them in connection with these observations?

"A. The observations on Lake Geneva were reported by an investigator named Lortet at the International Medical Congress in Berlin between the 4th and 9th of August, 1890. These investigations were published in the Centralbl f. Bakteriologie, 1891, Volume 9, p. 709, entitled 'Pathogenic Bacteria of the Deep Mud in Lake Geneva.'

"The observations as reported covered the examination of slime taken from a depth of forty to fifty meters, two kilometers from the shore. This deep mud was found virulent when inoculated into animals and was more virulent than that taken from near shore. The material taken 200 meters from shore, in the water four meters deep, was sterile, and animal experiments gave negative results. The statement is made that the staphylococcus pyogenes aureus, the tetanus bacillus, the bacillus coli and the bacillus typhosus were isolated from the deep mud two kilometers from shore, as already alluded to.

"No statements are made as to the methods of identification of these microbes. This was before the Widal test was used for the identification of the typhoid bacillus, and in view of the fact that no statements are made by this authority regarding his other methods of identification, the mere report of finding these organisms was not a satisfactory one. It may be added that the author makes a statement that every part of the lake from which material for investigation was taken contained chemically very pure water. Assuming that the pathogenic bacteria isolated were correctly identified, which seems rather a violent assumption in view of all the premises, there are no data as to the length of time that these organisms had been present in the sediment.

"I may add that Loeffler in his treatise on Water and Micro-Organisms, one of the leading German authorities on questions of this sort, in mentioning Lortet's report of the inding of the typhoid bacilli in the slime of Lake Geneva (page 592) puts an interrogation mark after the name typhoid bacillus, indicating

his skepticism as to the correct identification of this microbe. Personally, I share this skepticism and am unable to assume, in view of the facts given by Lortet in his report, that this identification was correctly and satisfactorily accomplished.

"Q. In the light of the present knowledge in regard to bacteriology, what importance do you attach to these observations in connection with Lake Geneva?

"A. I can attach no importance to them so far as shedding any light upon the longevity of the typhoid bacillus in sediment, since, even supposing that the identification were correct, there is nothing to indicate how long such bacilli had been present in the sediment of Lake Geneva.

"Q. Mr. Fuller in his testimony, in answer to the question, 'Had it ever been demonstrated by a bacteriologist that typhoid germs have lived in the sediment of a running stream?' answered, 'It has been demonstrated that they have lived for a long time in the sediment of lakes, and I do not consider that there is any weakness in the process of reasoning by which one steps from a lake to a river, provided, of course, that each of these waters are live waters and not subject to aseptic actions.' The further question, 'By whom has it been ascertained that the typhoid germ has been found to live in the sediment of a running stream or lake?' Answer, 'There are several over in Switzerland who made such investigations with a positive result showing the presence of typhoid germs in the sediment of Lake Geneva, and, I think, also Zurich.' I will ask you, do you regard the observations in Lake Geneva as quoted by Mr. Fuller as a demonstration that the typhoid bacillus has been found to live for a long time in the sediment of lakes?

"A. I certainly do not.

"Q. Will you please give your reasons?

"A. As already stated, there are grave objections to regarding Lortet's investigations in Lake Geneva, first, as demonstrating that the genuine typhoid bacillus was found in the slime at the bottom of the lake, as alleged. Second, that there are no data as to the length of time such bacilli had remained in the slime, assuming this author's identification to be correct.

"Q. Mr. Fuller in his testimony, in answer to the following question, 'Is not the length of time that a typhoid bacillus will live in a sediment more a matter of assumption than a matter of demonstrated proof?' Answer, 'I consider that it is a very clean cut demonstration that the typhoid fever germs may, do and have continued to live in the sediment of running streams.'

"Question, 'Who has demonstrated that it has ever lived a year?' Answer, 'I think that the conditions existing in a moist soil in many rural places in this country where typhoid fever prevails from time to time is proof that typhoid fever germs in the presence of moisture can live for such a term. If that were not so, then there would be an elimination of typhoid fever absolutely through the rural districts of this and all other countries.'

"I will ask you, professor, whether you know of any experiments or observations that have demonstrated that typhoid fever germs may and do and have continued to live in the sediment of running streams for a period of a year, and whether the conditions of moist soil furnish any criteria for the longevity of the typical bacillus in the sediment of a running stream?

"A. In reply I will say that I do not know of any experiments or observations that demonstrate that typhoid fever can live in the sediment of running streams for a period up to a year.

"In my opinion, the conditions obtaining in the moist soil are very different from those obtaining in the sediment of running streams, and I see no reason whatever for believing that the typhoid bacillus will live in the sediment of running streams for a similar period." (See Jordan's testimony, 6242 to 6248.)

Professor H. L. Russell, in response to the same questions, hereinbefore quoted which were asked of Professor Jordan, made the following answers to those questions:

"If the typhoid organism is imbedded in the sediment of a polluted stream, it would be surrounded entirely by a water medium in which there would be present a very large number of bacteria belonging to the saprophytic and probably the sewage

class, a number which would ordinarily be much larger than found in the water above. Doubtless the amount of by-products thrown off by the activity of these organisms, under the circumstances where these large numbers of bacteria would be found, would also be larger than would exist in the waters of the stream itself, taking into consideration the effect which the preceding experiments have revealed as to the prejudicial action of waters rich in bacterial life on the vitality of the typhoid organism in such water, it can hardly be considered that the vitality of the organism in the sediment of such a stream would be enhanced; even there are germs in the water itself, and there is no evidence which I know of that indicates that the typhoid organism would be capable of living in the sediment of such a polluted stream for a longer time than it would in the water of the same stream.

"The conditions which obtain in moist soil and the sediment of running streams are materially different. In the one case the soil is not completely saturated with water, for the soil particles are surrounded by a hygroscopic film which adheres to the particles themselves, but gives a considerable amount of pore space in the interstices which is filled with air. In the sediment found in running streams or lakes this condition would not obtain, as these spaces are entirely filled with water.

"Inasmuch as the conditions which would prevail in a moist soil, where the soil interstices were largely filled with air, and where the amount of water present in such interstices was confined to the thin hygroscopic film which is in contact with the surface of the soil grain itself, and inasmuch as the conditions herein described are materially different from those which obtain in the sediment found in a running stream, it is my opinion that the conditions which obtain in a moist soil, and the results which are here found, would not furnish any criteria for the determination of the longevity of the organism as found in the sediment of a running stream.

"The two conditions, as found in a moist soil and in the sediment of a running stream, for the foregoing reasons, are not comparable.

"In view of the fact that the conditions under which typhoid organism would be exposed in moist soil are different from those which are found in the sediment of a river, I would not consider that this would justify the assumption that it would live as long in the sediment of a river as would be the case if the exposure was made in moist soil.

"The reasons which I would assign for the above answer rest upon the fact that the water contents of the moist soils is confined to an exceedingly thin film surrounding the moist grain and that the large portion of the pore space between the soil particles is filled with air. These conditions do not obtain in the sediment of streams, and inasmuch as a prominent factor in the destruction of typhoid bacteria is that which comes from the effect produced by the sewage and water bacteria on the products formed by that growth, and inasmuch as the effect of this influence would be much less in the case of a moist soil than it would be in the case where the space between the soil particles was entirely filled with a watery medium, such as would be the case in the sediment in the bottom of a stream, I would not consider that the typhoid organism would be able to live as long in such sediment as would be the case in moist soil.

"The only experiment which I know of in which the claim is advanced that typhoid fever organism is capable of living for a long time in the sediment of lakes and rivers are those which were made by Lortet, of Lyons, France, which were presented to the Tenth International Medical Congress at Berlin, in August, 1890, and published in the Centralblatt fur Bakteriologie, 1891, Volume 9, page 709.

"On the basis of the experiments which I have been able to perform on the vitality of the typhoid organism when exposed to the waters of the Illinois River, and in view of the facts that the conditions which obtain in the bottom of that stream are such as would undoubtedly bring the typhoid organism in contact with even large numbers of water and sewage bacteria, and the products of their growth, that would often be the case in the waters of the stream itself, it is my opinion that the longevity

of the typhoid organism, when exposed in the sediment, as found in the Illinois River, would certainly be no longer than it would be in the superincumbent water above, and that it is quite possible that their longevity might even be shortened.

"Q. Mr. Fuller, in his testimony, stated that there are observers in Switzerland who made examinations with positive results showing the presence of typhoid germs in the sediment of Lake Geneva, and also Lake Zurich. Do you know anything about those observations to which Mr. Fuller referred?

"A. I do.

"Q. What were the facts and circumstances in connection with these observations?

"A. These observations which are referred to by Mr. Fuller are, I take it, those which are reported as made by Mr. Lortet, of Lyons, France, and were presented to the International Medical Congress at Berlin and published in the journal referred to above.

"It was stated in this paper that samples of the sediment were taken from Lake Geneva, at a distance of a mile and a quarter from shore, and at the depth of 120 to 150 feet, where the temperature of the water was approximately forty degrees Fahrenheit. It is further stated that the water over the places where these organisms were removed was a chemically pure water. It is further stated that an analysis of the samples of mud taken under these conditions revealed the germs of tetanus or lockjaw, typhoid fever, and possibly the tubercular organism.

"It is further stated in this paper that other samples were taken from a point 200 meters from shore and in water twelve feet deep, and that the mud under these conditions was found to be absolutely sterile.

"It is further stated that it was commonly observed that when portions of this lake sediment were injected into laboratory animals that it resulted in the production of malignant œdema, and the opinion is advanced that there may have been an actual multiplication of these disease producing bacteria in this mud for many generations.

"Q. In the light of the present knowledge in regard to bacteriology, what importance do you attach to those observations?

"A. From the results of the experiments which have been quoted it is my belief that these experiments were either carelessly performed or not carried out with sufficient detail and under sufficiently stringent precautions to warrant the conclusion which is drawn. The reasons for my belief, as indicated, are as follows:

"It is stated in this paper that samples were taken a mile and a quarter from shore, at a depth of 120 to 150 feet and at a temperature of forty degrees Fahrenheit, and that the water over these samples was a chemically pure water, and that in the mud found underneath this chemically pure water the germs of tetanus, typhoid, and possibly tuberculosis were present.

"If the sediment in the bottom of this lake contained the pathogenic organisms referred to, it would be probable that there would be some evidence of the organic pollution which would have resulted in the deposition of such organism say as typhoid fever. Moreover, he further states that in samples taken 200 meters from shore and in water twelve feet deep the mud was found to be perfectly sterile, a condition which is known and recognized by all bacteriologists of repute to be totally at variance with the actual facts of the case. There is no reference made in these experiments to the length of time which it is supposed that these typhoid, tetanus and tuberculosis organisms had presumably been exposed in the mud of this lake.

"The details which are given with reference to the identification of these organisms are exceedingly vague and indefinite.

"No bacteriologist who makes the statement that tetanus, typhoid, and possibly tuberculosis organisms are found under any conditions, can help laying himself open to the charges of careless manipulation because of the laxity of such statements.

"In view of the fact that the majority of the earlier findings with reference to the discovery of the typhoid organism, antedating the introduction of the agglutinating test, are generally regarded as more or less unreliable, and, inasmuch as no ade-

quate data are given with reference to the technical methods employed, and the accuracy with which they are carried out, it seems to me plain that the results of these investigation as reported are far from being a satisfactory demonstration of the presence of these pathogenic organisms in the sediment of this lake.

"The opinion is further advanced that there has been an actual multiplication of these disease producing bacteria in the mud of the lake, a multiplication which may have continued for many generations. This conclusion is so at variance with the generally accepted opinion of bacteriologists and sanitary experts, that any person advancing the same should take a special precaution to fortify his conclusions with very carefully controlled experiments and adequate data, so that the course of reasoning which would lead him to draw these conclusions might be closely followed.

"It is my opinion, therefore, that the conclusions established in this paper are not justified from the experiments as presented. I find that this opinion is shared by other bacteriologists and discredit is thrown on the same by the well recognized water expert, Professor Ferdinand Loeffler, of Greifwald Germany, who, in his book on 'Water and Water Organisms' page 592, refers to Lortet's experiments, and places after them an interrogation point, making it evident that he regards the conclusions drawn from his work as not perfect from the facts as stated."

A question put to Professor Russell, incorporating the testimony of Mr. Fuller, hereinabove quoted, elicited the following answers:

"From the observations quoted in the question and to the answer to the preceding question, I do not consider that the result of observations so reported a demonstration sufficiently full and accurate that a typhoid bacillus, so found, as to say it was capable of living in the sediment of the lake so mentioned for a long time.

"On the basis of the results as reported by Lortet, which

were quoted by Fuller in affecting questions of the life and conditions known to exist with reference to the vitality of the typhoid fever organism when placed in moist soil, also to the fact that the conditions which here obtain are by no means similar to the conditions which would obtain if such typhoid organisms were deposited in the sediment of running streams, in place of moist soil, I should say I know of no demonstration that affords sufficient proof that the typhoid organism is capable of living for the period of a year." (6528 to 6536.)

Professor E. G. Smith testified upon this subject, in part, as follows:

"Well, in moist soil the organism is fixed, and new conditions are surrounding the organism. It is open to the air. It is subject to a thin superficial layer near the air. The air percolates through the soil. That condition does not obtain in the sediment of a stream. It is true that the sewage of the stream is the cause of the sediment, and it therefore follows that whatever toxins of the water have access to the organisms in the sediment of the stream so that the conditions are entirely separate, one being fixed and the other having the toxic effect of the excretions from other organisms, finding free access to them, and, more than that, it would be subject to variations in temperature. It might, at least.

"Q. Does the time that a typhoid bacillus will live in moist soil furnish any criterion for its longevity in the sediment of a running stream?

"A. In my judgment, conditions are so different that what is true of one should not be applied to the other.

"Q. Are the two conditions comparable?

"A. In my judgment or opinion, they are not comparable.

"Q. Would the fact that a typhoid bacillus lives several months in the moist soil justify the assumption that it would live for the same length of time in the sediment of a river?

"A. For the reasons I have already stated, it is my opinion that the assumption that it would live for the same length of time in the sediment of a river as it would in moist soil is untenable ground.

"Q. Mr. Fuller in his testimony, in answer to the question, 'Is not the length of time that a typhoid bacillus will live in a sediment of a stream more a matter of assumption than a matter of demonstrated proof?' said, 'I consider that it is a very clean cut, demonstrated fact that typhoid fever germs may and do and have continued to live in the sediment of running waters.' 'Q. For what length of time?' 'A. I should say for a month or more, possibly, in cases, for years.' 'Q. Who has demonstrated that it has ever lived a year?' 'A. I think that the conditions existing in a moist soil in many rural places of this country where typhoid fever prevailed from time to time is proof that typhoid fever germs in the presence of moisture can live for such a time. If that were not so, then there would be an elimination of the typhoid fever absolutely through the rural districts of this and other countries.' I want to ask you, Professor, whether you know of any demonstration that shows that typhoid fever germs may and do and have continued to live in the sediment of running streams for the period of a year?

"A. In reply to that question I would say that I do not know of any demonstration of typhoid fever germs having lived for a period of one year in the sediment of a running stream.

"Q. What is your own opinion as to whether a typhoid fever germ will live in the sediment of a running stream for the period of a year?

"A. In my opinion, the typhoid fever germ would not remain in the sediment of a running stream for that length of time. The agencies of removal would be at work on the destruction of the germ, for the reasons stated." (6764 and 6765.)

Professor W. P. Mason also testified upon this subject, and his testimony, in part, is as follows:

"Q. Will you differentiate between conditions that obtain in moist soil and the sediment of a running stream?

"A. The difference is one of water contents. In one case you have only moisture present and in the other you have water present in quantity.

"Q. Does the time that a typhoid bacillus will live in moist

soil furnish any criteria for its longevity in the sediment of a running stream?

"A. I should not expect that the cases would be parallel. That is my opinion.

"Q. Are the two conditions comparable?

"A. I think not.

"Q. Would the fact that a typhoid bacillus lives for several months in moist soil justify the assumption that it would live for the same length of time in the sediment of a river?

"A. I should say that it would not justify that assumption, and I refer you again to the Massachusetts Board of Health tank experiment to which I referred. The bacillus coli communis not having been found in that sediment, and it being well known that the typhoid bacillus cannot stand adverse conditions to the same extent as the bacillus coli, if the bacillus coli could not live, then the typhoid could not be there.

"Q. Do you know of any bacteriologist since the birth of bacteriology that has demonstrated by any experiment that typhoid germs would live in the sediment of lakes or rivers for a long period of time?

"A. I do not. (6919.)

"Q. Is there such a thing as purification of soil?

"A. Yes; sir; there is such a thing as purification of soil, although it is a slow process. The best illustration that I can give of that is to refer you to an article by Savage in the Journal of the Sanitary Institute, October, 1903, page 442, in which he refers to the purification of soil and says the 'Gradual diminution and disappearance of bacillus coli is of interest from the point of view of specific contamination. It is a more resistant organism than the typhoid bacillus. It is a fair presumption from this that the typhoid bacillus, if present in such soils, would also rapidly die out, and that the danger of specific typhoid contamination from building on such made soil can be neglected.'

"Q. I want to ask you, Professor, whether you know of any demonstration that shows that typhoid fever germs can and do

and have continued to live in the sediment of running streams for a period upwards of two years?

"A. I know of no such demonstration." (6918-6920.)

From the foregoing testimony in regard to conditions that obtain at Zurich, Switzerland, which, no doubt, was confounded with the Lortet observation, as hereinabove referred to in the testimony, the inferences drawn from that investigation by Professor Sedgwick and Mr. Fuller are plainly not warranted.

The testimony of Professor Jordan and Professor Russell, as hereinabove set forth, clearly shows that at the time Lortet claimed to have discovered a typhoid bacillus in the sediment of Lake Geneva bacteriology was practically in its infancy, and determinations made at that time are not accepted to-day.

This fact is sufficiently set forth in the testimony of Professors Jordan and Russell above quoted. Mr. Fuller's comparison of conditions that exist in moist soil with the sediment of a polluted river is so unwarranted, in the light of scientific knowledge, as not to require the mind of a scientist to discern the fallacy.

However, in the explanation given wherein the different conditions are differentiated by Professors Jordan, Russell, Smith and Mason, as above set forth, the conclusion is irresistible that the comparison is not an apt one, and conditions of typhoid longevity in moist soils furnish no criteria by which the length of life of a typhoid germ in the sediment of a polluted stream may be measured.

To sum up the conclusions which the above testimony warrant and justify, it is apparent that, in the absence of any personal experimental data upon the longevity of a typhoid germ in the sediment of a river by Professor Sedgwick or Mr. Fuller, the assumption that a typhoid germ will live for a considerable period, measured by months or years, is a gratuitous one and not established by any testimony introduced in the evidence in this case, and, that being the case, any inferences drawn and opinions expressed as to the longevity of a typhoid germ in sediment, based upon the longevity of the typhoid as evidenced

by Lortet's alleged observation at Lake Geneva, or in moist soil, are not borne out by sufficient evidence to have any weight in deciding the questions involved in this controversy.

Scouring of the Illinois River.

In the testimony presented in this case in behalf of complainant, nearly all of complainant's witnesses assumed that the Illinois River was subject to scouring in times of freshets or a sudden rise in the stream.

The evidence in this case shows that not a single witness who testified to this condition, called by the complainant, had ever made a personal investigation of the Illinois River or had ever traveled from the mouth of the Illinois River to La Salle; but that the information which they possessed in regard to the physical conditions of the Illinois River was derived from a study of maps and charts. This statement applies to the witnesses who qualified as sanitarians and epidemiologists.

Mr. Gardner S. Williams testified that he had not been up the Illinois River at any time or at any stage of water. (2534.)

The same statement was made by Mr. Whipple. (2099.)

Professor Sedgwick states that he was familiar with the general physical characteristics of the Illinois River from studying the maps and talking with men who had been up there, "not from any personal examination." (2262.)

Mr. Allen Hazen also testified that he had never traveled over the whole distance from the Drainage Canal down the Illinois River to the Mississippi. (2807.)

Mr. George W. Fuller in his testimony plainly shows that he secured his information of the Illinois River from memorandums, reports, and not from personal investigation, for nowhere in his testimony does it appear that he had any personal knowledge of the entire course of the Illinois.

With this limited personal knowledge of the Illinois River, based not upon any personal observations made as to whether the Illinois River scoured or not, these learned epidemiologists and sanitarians assumed that *the Illinois River from La Salle*

to Grafton, a distance of 225 miles, with a fall of only thirty feet, with four dams, backing the water up the stream, beginning with Kampsville, La Grange, Copperas Creek and Henry, was a river that scoured in times of freshets, caused by heavy rains or melting snow, such as would obtain in some of our New England streams.

The fact as to whether the Illinois River scours or not can best be ascertained from the testimony of witnesses who have lived upon the Illinois and have been acquainted with its hydraulic conditions for a great many years.

The evidence of reputable witnesses in this case establishes conclusively that the Illinois River is not a river wherein scouring takes place. By reference to the testimony of the United States Engineers at Kampsville and the employes of the Government located at that point this statement is fully borne out and sustained.

Mr. C. V. Brainard, a civil engineer in the employment of the United States Government, in charge of the dredging operations on the Illinois River for the last twelve and one-half years, from Copperas Creek to the mouth of the Illinois River, testified as follows:

"Q. Do the channels in the new bars that are formed sometimes fill up?

"A. The dredge channels fill up at times; yes, sir.

"Q. From what cause?

"A. Between Kampsville Lock and the mouth of the river it is usually formed by the backwater of the Mississippi. There are times at which the creeks, pouring out a flood at certain stages of the river, will fill up the channel immediately below the mouth of the creek.

"Q. What is the effect upon the sedimentation in the Illinois River of a flood?

"A. *My experience has been that there is no effect on what has already been deposited.*

"Q. Does it have the effect to increase the amount of sedimentary matter or material?

"A. Well, that I couldn't say. After floods, after high waters, we frequently find some of our channels filled up. That is usually in parts of the river that are affected by back-water from the Mississippi. This may be caused by two reasons, either that the water that is entering the river from the Mississippi is full of sediment which is deposited when the current is slack, or it may be that the water coming from above in the Illinois River deposits the sediment into the slack water that is formed from above in the Illinois River by emptying into the backwater of the Mississippi. The deposits may be made in either of the two ways.

"Q. Before the opening of the Drainage Canal, in January, 1900, did the Illinois River scour and clean itself in times of high water?

"A. I never knew of it doing it.

"Q. Before and since the opening of the Drainage Canal, if sedimentary matter is deposited in the Illinois River, how is it removed?

"A. The only way that it is removed is by dredging it or some mechanical process. The river does not clean itself at all that I have ever been able to find out. During high water in the Mississippi the river flowed up stream above this point about sixty miles." (3140-3141.)

James R. Fuller, and overseer in the employ of the United States Government for thirteen years, who has charge of the repairs and construction work and dredging operations under the supervision of the assistant engineer, Mr. W. C. Brainard, testified as follows:

"Q. Where are the bars formed, as a general rule, with reference to the mouth of tributaries of the river?

"A. Generally below the mouths of these tributaries.

"Q. What causes these formations?

"A. The flood washes it down from these tributaries, the deposits are washed down by the floods out of these tributaries.

"Q. Do the channels cut in these bars ever fill up?

"A. Yes, sir.

"Q. From what cause?

"A. Freshets out of these tributaries.

"Q. Have you occasionally redredged the channel formerly dredged out?

"A. We have. * * *

"Q. What is the effect, so far as sedimentation is concerned, of a flood in the Illinois River?

"A. It would make some deposit along the banks. At the lower end, if we have backwater from the Mississippi, it is liable to make deposits in the main channel.

"Q. Does it have the effect to lift up and remove sedimentary matter previously deposited either in the channel or along the banks of the river?

"A. I have never seen any effect of it.

"Q. In the Illinois River, if sedimentary deposits are made or occur, what is the only means of removing them?

"A. Dredging, as a rule, in some form or other.

"Q. Did the Illinois River, before the opening of the Drainage Canal, scour or clean itself in times of flood?

"A. Not as I ever saw.

"Q. Since the opening of the Drainage Canal, does the Illinois River scour or clean itself, in either times of flood or in other stages of water?

"A. No, sir.

"Q. Since the opening of the Drainage Canal, if sedimentary matter occurs in the Illinois River, what is the only means of removing it?

"A. Dredging." (3145 and 3146.)

Cross-Examination.

"Q. You don't mean to say that in times of high water the river does not cut through these bars and deposits and at places form new channels, do you?

"A. Yes, sir; that is what I mean to say. It doesn't do that. The river don't cut out channels, don't change a channel from itself. It won't cut a channel through these bars.

"Q. Then the channel, you say, never changes in either high or low water?

"A. Not in my experience. It never changes from the river itself. The current never changes. We changed the channel occasionally, dredging. I never saw this river change a channel from the effects of the water.

"Q. You are not an engineer?

"A. Yes, sir; I have studied civil engineering." (3147.)

Edward Dougherty, who has been in the employ of the United States Government on the Illinois River since the spring of 1882 as a carpenter and cranesman on the dredges, and has been connected with the business of dredging the Illinois River for twenty-one years from six miles below Havana to six miles above Grafton, testified as follows:

"Q. What is the purpose of dredging?

"A. To deepen the channel.

"Q. In deepening the channel, do you dredge out bars which are formed in the river?

"A. Yes, sir.

"Q. Where, as a general rule, do these bars form?

"A. Below creeks.

"Q. What occasions the formations at such points?

"A. The creeks overflowing and throwing out their sediment into the river.

"Q. Have you had occasion during your experience to dredge out the same channels in the Illinois River more than once; if so, where and how frequently at each place, commencing at the upper portion of the river and proceeding towards Grafton?

"A. As far up as I can remember distinctly, the first was at the mouth of Sugar Creek. I think we dredged that once after the original dredging, and the next was down there at Otter Creek. I think we dredged that twice after the first dredging. I don't believe I remember any more places. We have dredged several places three or four times.

* * * * * *

"Q. Are you familiar with the Illinois River and have you been upon it in all of its various stages from high to very low water?

"A. Yes, sir.

"Q. What is the effect upon the bottom sides of the channel of the Illinois River of floods in the river as to the deposit of sediment?

"A. I have not noticed any serious results from the sediment.

"Q. In times of flood or high water in the Illinois River is the sediment which has been deposited by the action of the water washed out or is more sediment deposited? *In other words, does the river scour?*

"A. No, sir.

"Q. After a flood in the Illinois River, is there more sediment in the bottom and along its banks or less than before a flood?

"A. More sediment everytime there is a flood." (3123-3124.)

Frank Tozen, a steamboat engineer in the employ of the United States Government at Kampsville as an engineer and blacksmith, testified, in part, as follows:

"Q. What causes the formation of bars in the Illinois River?

"A. I think very nearly the whole cause is the sediment that comes out of the creeks. After each high water there will be a sediment of an inch to two inches, sometimes maybe three inches all over the banks. On the flats will be an inch to three and four inches of sediment after a long high water. This year there was about three inches.

"Q. When there is high water in the Illinois River, does it wash out the sediment or cause more sediment to settle?

"A. I think it causes more sediment to settle. *There isn't current enough in this river to wash out anything.*

"Q. Have you ever dredged out a place upon the Illinois River where afterwards you were not able to find the channel again?

"A. Yes, sir.

"Q. Where was that?

"A. Otter Creek. A storm came right after we left there and after the storm we went back there and couldn't find where we left. That was two or three weeks after we left there. I think it was two weeks.

"Q. Did the channel fill up because of a flood in Otter Creek?

"A. Yes, sir." (3103.)

John Weimer, for sixteen years employed by the United States Government as dredging engineer on the Illinois and Mississippi Rivers, and who was acquainted with the Illinois River from La Salle to the mouth of the Illinois, and who has dredged from Hennepin, which is immediately below La Salle, to the mouth of the Illinois River, and who was acquainted with the Mississippi River from Winona to twenty miles below St. Louis, testified, in part, as follows:

"Q. How does the Mississippi River and the Illinois River compare as to their channels?

"A. They do not compare at all, the two rivers. Why, one would stay stationary in its place and the other moves.

"Q. Which one moves?

"A. The Mississippi.

"Q. And the Illinois stays stationary?

"A. Yes, sir.

"Q. Is it the Mississippi River that scours?

"A. Yes, sir.

"Q. How about the Illinois, does it scour?

"A. No, sir.

"Q. Will high water in the Illinois River scour out the bed of the river?

"A. No.

"Q. How are these bars removed when they are removed in the river?

"A. By dredging. We removed them by dredging. I have had experience where we dredged out the channel and it immediately filled up and we had to dredge it out again.

"Q. When matter is deposited on the bed of the Illinois River do you know of any way by which that deposit can be removed except by dredging?

"A. No, sir.

"Q. Does high water or current change the channel in the Illinois River?

"A. No, sir.

"Q. What effect does current and volume of water have upon the channel of the Mississippi River, if you know?

"A. Well, I have seen where the channel would be one time and after high water it would be altogether removed from there and be another place.

"Q. That condition is common on the Mississippi, is it not?

"A. Yes, sir.

"Q. Have you ever found that condition to exist upon the Illinois?

"A. No, sir." (3149 to 3152.)

The foregoing testimony of the witnesses called by the defendants, who are or were in the employ of the United States Government, connected with its dredging fleet, located at Kampsville, engaged in the dredging of the channel of the Illinois River, show conclusively that the Illinois River is not a river that scours its bed in times of flood or freshet, but, on the contrary, when matters in suspension eventually find a resting place on the bottom of this river, the only way they can be removed is by the operation of a dredge; and defendants submit that all the fine spun theories in regard to the scouring of the Illinois River, that were presented in this case by the epidemiologists and sanitarians of complainant, who had no personal knowledge or experience with the conditions obtaining on the Illinois River, show conclusively that theories do not always conform to facts.

A comparison between the conditions of the Mississippi and the Illinois, as above testified to, shows how different those two rivers are in respect to scouring. While the Mississippi has a rapid flow, changing its channel in a comparatively short time

from one side of the river to another, to use the language of one of the witnesses above quoted, "There is not current enough in the Illinois River to wash out anything." This testimony emphasizes the fact perhaps more than can be fully appreciated, without an exhaustive examination of the entire testimony in this case, how the learned and distinguished epidemiologists and sanitarians of complainant, in their effort to carry out a preconceived theory, unsupported and uncorroborated by personal observation or scientific demonstration, have committed themselves to a statement of facts when physical conditions known to exist disclose the contrary to be true.

The physical conditions that exist in the Allegheny River, the Hudson River, the Potomac River, or rivers of like character, find no parallel in the physical conditions that obtain in the Illinois River.

In view of the foregoing testimony, given by men who have spent years of their lives in operating dredges upon the Illinois River, who testify in their simple and candid manner that the Illinois River does not scour, all the labored theories of complainant, based upon typhoid germs coming from the sewers of Chicago and resting upon the bed of the river at Peoria and at points above, in large deposits, in a virulent and quiescent condition, awaiting a sudden freshet to flush them from their resting places down the Illinois into the Mississippi and thence into the intake, carrying sickness and death to the inhabitants of St. Louis are seen to be plainly a fiction, unworthy of acceptation, based upon no facts, scientific or otherwise, established in this case; but are fantastic creations emanating from and existing only in the mind of the sanitarian and epidemiologist that conceived them.

Time of Flow Between Chicago and St. Louis.

Two experiments were made to ascertain the time that it would require a float to pass from the mouth of the Chicago River to the City of St. Louis. One of these experiments was made under the direction of Professor Van Ornum, a witness

of complainant; the other under the direction of Mr. Isham Randolph, the chief engineer of the Sanitary District of Chicago. When Professor Van Ornum made his experiment in the month of March, 1903, the volume of discharge of the Illinois River at Peoria was 2,473,122 cubic feet per minute, and the volume of discharge of the Illinois River at the same place immediately before Mr. Randolph made his float experiment was 565,440 cubic feet per minute. (6663.)

The conditions under which these two experiments were made as to the manner of carrying out the observations were, to all intents and purposes, similar; floats were employed by each observer of a similar character, and these floats were kept in the center thread of the channel for the entire distance. When these floats, operated upon by the currents in the river or the force of the wind, were driven from the channel, they were immediately replaced and the observation continued. Under the stage of water existing at the time that Professor Van Ornum made his observations, the time given by him for these floats to pass from Chicago to St. Louis was ten and one-half days, while the result under Mr. Randolph's observation was given as eighteen and one-half days.

These two periods of time, as given by these two observers, represented the minimum time that it would take a float, kept in the center thread of the channel of the Chicago River, the Drainage Canal, the Desplaines, Illinois and the Mississippi Rivers, to travel from Chicago to St. Louis. At the time that Professor Van Ornum made his experiment the volume of discharge indicated a high flood condition in the Illinois River, while at the time that Mr. Randolph made his observations the stages of the river might be characterized as being a full river, but not a flood.

While these interesting observations, as above described, indicate the minimum time required for a float to pass from Chicago to St. Louis, under conditions that existed at those times, when by artificial agencies these floats were kept constantly in the center thread of the channel, they do not in either

case prove that a typhoid germ, assuming its longevity to be indefinite, unassisted by any artificial agency, to remain in the center thread of the channel, would make the journey under similar conditions in the same length of time. (1749.)

It is in evidence in this case that in times of high flood the amount of land inundated along the Illinois Valley from Lake Joliet to the mouth of the river is in the neighborhood of 400,000 acres, and during the time of each of these float observations the evidence shows the bottom lands along the Illinois River were inundated, and in places, at the time that Professor Van Ornum made his observation, the water was very high and the bottom lands and overflowed lands along the Illinois River were very extensive. (7333.)

During the time that Professor Van Ornum made his experiment he stated that "the state of the river throughout our observations in the Desplaines and Illinois Rivers, being in a condition of overflow, caused them (the floats) to rather seek the banks.

"Q. The current outward?

"A. Yes, sir.

"Q. During that time was it found that they were aground?

"A. Quite often.

"Q. And when that was done they were released and taken back to some deeper point?

"A. Taken back.

"Q. Did those floats in the Desplaines River keep abreast of each other if they were floating rapidly?

"A. That would depend largely on the wind, sir, whether they would keep abreast of each other or not. The effect of the wind would be small compared with the effect of the current upon the floats, but it would have an effect, a certain effect."

It was generally noticed that during a half a day or a day's run that the floats would work towards the leeward side of the river. If the wind is across stream during a number of hours' run, greater or less depending upon the velocity of the wind, the floats in general will be influenced in the direction of the wind to that extent. (1749 and 1750.)

If these floats had not been kept by human agencies in the center thread of the channel, it is evident from the testimony above quoted that they never would have reached St. Louis in anything approximating ten and one-half days.

The evidence in this case plainly defines a typhoid germ as a particulate particle having presence and form (910), and responding to the law of gravitation. Should such a germ find its way into the waters of the Chicago River, the Drainage Canal, the Desplaines River and the Illinois River, be carried hither and thither by the cross-currents that obtain in those streams, and experience the effect caused by the winds, is it an unreasonable inference to draw from the evidence of the floats to say that the time consumed by typhoid germs, or any given body of water containing them, to pass from Chicago to St. Louis would be far in excess of the time represented by the minimum time required for the floats kept in the center thread of the channel by artificial means?

Taking into consideration that during periods of overflow the currents of the river naturally would be towards the overflowed lands, carrying these germs among the grass and vegetation that obtain thereon, where the water was quiescent, affording every opportunity for sedimentation and small opportunity for these germs to return back to the channel again, it seems but reasonable to assume that the time required during high stages of the river, under conditions which prevail in the Illinois River, would be greater by far than that which would be represented by a float kept in the center thread of the channel for the whole distance by artificial means.

The evidence in this case shows, according to Professor Van Ornum's testimony, that at times of high water in the Illinois River the floats sought the banks, the currents extended outward and the floats went aground (1749), indicating and showing that a typhoid germ, less capable of resistance than were these anchored floats, would follow the course of least resistance, and when once arrested, by sedimentation or otherwise, would remain thus arrested unless disengaged by natural

agencies, and again taken back into the channel where the current was swiftest, all of which, on the assumption that it still lived, would cause a delay in its journey, and under no conceivable circumstances would it be able to make that journey in a time as limited as that measured by the float experiment.

If the inferences as above indicated correctly approximate true conditions which obtain during times of flood, when the current of the river is swiftest, the converse of the proposition would be equally true during periods of low water; so, while defendants do not attack the validity of the float experiments, they assert that they conclusively demonstrate but one thing, and that is that under the two experiments, under different conditions, it requires ten and one-half days for a float kept in the center thread of the channel by artificial means to travel from Chicago to St. Louis, and eighteen and one-half days, under different conditions, to make the journey.

Defendants contend that the time required under any and all conditions for a given body of water, whether the same contains typhoid germs or matters in suspension, leaving the Chicago River to make the journey to St. Louis, would be greater in point of time than that measured by the float experiments, and if in that body of water are contained typhoid bacilli, which are particulate particles, affected by the law of gravitation, carried by currents and cross-currents out over the overflowed lands, among the weeds, underbrush and trees and back again into the stream, and then out of the channel into the lakes and slack water portions of the Illinois River—to seriously contend that such a journey could be made in a period commensurate with the float experiment is to do violence to our reason and to assert as a fact that which is contrary to our judgment.

Under existing conditions in the Illinois River, to assert that a typhoid germ could, under any conditions or circumstances, make the journey from Chicago to St. Louis, and enter the intake tower at the Chain of Rocks, is too speculative and uncertain to cause serious alarm.

Dr. Ravold's Bacillus Prodigiosus Experiments.

Three experiments were made by Dr. Ravold with bacillus prodigiosus. The first of these was on August 31, 1900, when forty gallons of a broth culture of bacillus prodigiosus were emptied into the Mississippi River just below the mouth of the Illinois River. (906.) On September 3d, four days later, this organism was found in a sample of water collected from the channel of the river at Alton. It seems impossible to attribute the bacillus prodigiosus found in the Mississippi River at Alton to the organisms placed in the Mississippi River at Grafton. Professor Van Ornum has testified that in his float experiments the time for the float to pass from Grafton to Alton, a distance of 15 miles, was six hours and thirty-six minutes. (1742.)

There are no eddies or backwaters in this stretch of river between Grafton and Alton; the current is swift and the whole body of water passing Grafton would undoubtedly flow by Alton long before a four-day period was past.

Dr. Ravold himself does not claim anywhere in his testimony that defendants can find that the organism discovered on September 3d in the channel at Alton was one of the organisms deposited by him in the waters of the Mississippi immediately below Grafton.

The second experiment made by Dr. Ravold was on September 20th, when the same amount of broth culture of bacillus prodigiosus was emptied into the Mississippi River at Grafton. (907.)

The banks of the Mississippi River, according to the description of Mr. Whipple (2150), "from Grafton to the mouth of the Missouri, are straight, and form what is known as a straight reach, barring certain sinuosities. The channel changes from side to side a number of times during that reach of the river, passing from a position near the right bank to a position near the left bank." (2151.)

On September 23d, three days later, at the Illinois shore,

Chain of Rocks, B. prodigiosus was found; on October 18th, twenty-eight days later, from the laboratory tap of the City Hall, B. prodigiosus was found, and on October 24th, on the Illinois shore, Chain of Rocks, thirty-four days later, B. prodigiosus was found. (908.)

Professor Van Ornum testified that the time required for a float to pass from Alton to the intake of the Chain of Rocks was four hours and thirty-four minutes, which, added to the six hours and thirty-six minutes, makes eleven hours and ten minutes required for water to pass from Grafton to the Chain of Rocks. (1742.)

Taking into consideration the character of this stretch of the Mississippi River, as heretofore referred to in the testimony of Mr. Whipple, and the fact that floats pass from Grafton to the Chain of Rocks in eleven hours and ten minutes, and the additional fact that B. prodigiosus was found three days, twenty-eight days and thirty-four days, respectively, after it was deposited in the river at Grafton, it is clear that B. prodigiosus has its natural habitat in the waters of the Mississippi River; and the fact that such a long period of time had elapsed from the time that this culture was deposited until an organism of the same description was found, demonstrates beyond all question that the organisms found were not the ones deposited in the river by Dr. Ravold.

The volume of water into which this barrel of culture was deposited in the river at Grafton would have passed down the river past the Chain of Rocks in eleven hours and ten minutes, and no explanation has been offered by the investigator who made this experiment as to what became of these organisms from the time they were deposited in the river until they were discovered weeks afterward, and the natural inference is that these organisms, like the one discovered by Professor Jordan in 1899 in the Illinois River, are natural inhabitants of the Mississippi River water.

In the third experiment 107 barrels of forty gallons each of the culture of bacillus prodigiosus, consisting of one thou-

sand million to the cubic centimeter, were alleged to have been deposited in the Chicago Drainage Canal at the Town of Lemont on the afternoon and evening of the 6th of November, 1901, during a period of from four to eight hours. Immediately after said barrels were emptied into the Drainage Canal, laboratories which had been established at Lockport, Joliet, Peoria, Grafton and at the intake tower of the St. Louis waterworks, Chain of Rocks, were notified, and samples were collected at each of these places every hour of the day and night for purposes of bacterial analyses for the ascertainment of this bacillus prodigiosus. At Lockport these hourly samples, taken day and night, were taken from November 7th to November 25th, a period of eighteen days; the total number of samples taken was 432. At Joliet the same hourly samples, taken day and night, were taken from November 7th to November 25th, a period of eighteen days, with a like total number of samples of 432. At Peoria these samples were taken day and night from November 8th to November 30th, a period of twenty-two days, which, calculated as to samples, amounts to 528. At Grafton these hourly samples were taken day and night from November 12th to December 15th, a period of thirty-three days. The number of samples by calculation amounted to 792, of which 384 were analyzed by Dr. Ravold. The number of samples taken hourly, day and night, at the Chain of Rocks was 770. Hourly samples were taken day and night at the laboratory tap from November 20 to March 1, 1902, a period of 100 days, which amounted to about 2,400. The aggregate amount of samples analyzed, based upon the foregoing statement of hourly samples taken, amounted to 5,304. On December 4th, at 8:45 o'clock A. M., one bacteria of the bacillus prodigiosus was found at the intake tower of the Chain of Rocks. On December 5th, at 9 A. M., one bacillus prodigiosus was found at the intake tower, Chain of Rocks. On December 8th, at midnight, one bacillus prodigiosus was found at the intake tower, Chain of Rocks. On December 6th, at 8 A. M., at Grafton, one bacillus prodigiosus was found. On

December 7th, at midnight, at Grafton, one bacillus prodigiosus was found; and these five organisms were all the organisms of prodigiosus that were found in the examinations made from Lockport to the intake tower at the Chain of Rocks and the laboratory tap in the City of St. Louis.

This statement substantially sets forth the experiments made by Dr. Ravold known as the prodigiosus experiment. (779-788, 913-27.)

The most remarkable feature in connection with this so-called experiment upon the prodigiosus is the undisputed fact that the evidence in this case fails to show that any prodigiosus were ever deposited in the Drainage Canal at Lemont. Dr. Ravold stated, in response to this question:

"Q. Have you any personal knowledge of how the contents of those barrels were dumped into the canal?

"A. I was not present.

"Q. I believe you stated that your brother made the deposits?

"A. Yes, sir. I can tell you how the barrels were prepared, the kind of bungholes in them, etc., because that was done here." (911.)

This testimony plainly shows that Dr. Ravold had no personal knowledge that these barrels were ever dumped into the Drainage Canal, as he testified that he was not present.

On page 783 of the testimony Dr. Ravold states:

"Now, Mr. Ravold left Lemont rather hurriedly and went to Joliet, then to St. Louis, bringing with him six samples from barrels as they were discharged into the canal. These samples I examined myself, and they contained over five hundred million to one thousand million prodigiosus to each cubic centimeter of broth. The bacillus was not found by Mr. W. G. Kirschner, who was stationed at Joliet.

"Attorney General Hamlin: Now, wait a minute, Doctor. You are stating now not what you know yourself, but from what they have reported to you.

"A. They reported to me; in fact, I went up there.

"Q. Then you know this personally?

"A. Well, I didn't know. I didn't examine these samples myself. We will get to my own work in this experiment, if you wish." (783-4.)

The bacteriologists who were located at Lockport, Joliet and Peoria were Dr. Kirschner and Dr. Rush, and Attorney General Crow stated on page 928:

"I stated, if you will remember, that when Dr. Kirschner testified on the stand that I would recall him."

It is a remarkable fact that if any value was placed upon this prodigiosus experiment, complainant did not recall Dr. Ravold's brother and have him testify that he emptied these barrels, containing the culture of prodigiosus, into the Chicago Drainage Canal. But the record in this case will not disclose that he was ever recalled, nor is there any legal proof presented on the part of complainant to show that these 107 barrels were ever deposited into the Drainage Canal at Lemont. The only evidence upon that point is the testimony of Dr. Ravold, who said that he was not present when his brother deposited these organisms into the canal. Consequently, the value of this experiment could not have been considered as of much consequence by the complainant, in view of the fact that essential testimony was not produced.

The attorneys who represented the State of Missouri are too able and learned to have overlooked such an important piece of evidence, if they deemed this experiment as of any importance in shedding light upon the life of a typhoid organism.

Another significant fact which the evidence fails to disclose is why the bacteriologists, Dr. Kirschner and Dr. Rush, who had charge of the laboratories at Joliet and Peoria, at the time that this experiment was under way, were not called to the witness stand to give the results of their examination of the waters at Lockport, Joliet and Peoria, and what the results of those determinations were. The fact that an experiment such as this, costing a great amount of money to carry out, was not proven in this case, only a part of the experiment being

submitted, plainly indicates that the complainant failed to secure evidence of the character that they were looking for, and hence had very little faith themselves in the value of this experiment, as shedding light upon the question of the longevity of a typhoid germ.

If 107 barrels of forty gallons each of prodigiosus were dumped into the Drainage Canal at Lemont, and samples were taken hourly at Lockport and Joliet, and this organism was not found, and the same results were obtained at Peoria, does it not raise a reasonable doubt as to the identity of the organisms which were found at St. Louis and at Grafton, with the organisms alleged to have been deposited in the Drainage Canal?

In view of the fact that the Commissioner who was appointed to take testimony in this case was not empowered by the Court to pass upon the competency of evidence, the defendants in this case offered evidence upon the experiment, notwithstanding the fact that as a legal proposition, in the absence of having proven that these germs were deposited in the canal, the experiment is incompetent and non-admissible as a fact or circumstance to be considered by the Court in this case.

Before submitting to the Court the opinion of expert witnesses, who read the testimony of Dr. Ravold in regard to this experiment, under the assumption that these germs were deposited in the Drainage Canal, the defendants suggest to the Court that in view of the first and second experiments introduced in evidence in this case, and above referred to, showing the presence of these prodigiosus organisms in the waters of the Mississippi, twenty-eight and thirty-four days after they were deposited at Grafton, and taking into consideration that this organism was found by Mr. Fuller in the waters of the Ohio and by Mr. Hill in the same stream, and by Professor Russell in various watercourses in Wisconsin, as well as having been found by Professor E. O. Jordan in the waters of the Illinois, prior to the making of this experiment, all of which has been referred to in a previous part of this brief, the conclusion seems to be positive and incontrovertible that the organisms found by Dr.

Ravold in the waters of the Mississippi, after this latter experiment, and the organisms found after the first two experiments, are organisms whose natural habitat are the waters of the Mississippi River; for, if it were not so, why did not Dr. Kirschner discover these organisms at Lockport and Joliet, immediately below the point where they were said to have been deposited in the Drainage Canal, and why did Dr. Rush not find them at Peoria, when we take into consideration that these observers were taking hourly samples, day and night, looking for this organism known as the prodigiosus?

From all the facts and circumstances in connection with this experiment that have been introduced, as well as those that have failed to find their way into the evidence in this case, the defendants contend that the organisms discovered in the waters of the Mississippi and in the tap water at St. Louis have not been proven or established by competent proof to be the organisms that were deposited in the Mississippi River or alleged to have been deposited in the Drainage Canal by Mr. Ravold.

Professor John H. Long, one of the witnesses for the defendants in this case, had submitted to him a hypothetical question involving substantially all the facts connected with this prodigiosus experiment, and he testified as follows:

"Considering the longevity of the typhoid bacillus, as measured by the longevity of the bacillus prodigiosus, which consideration in no way involves a knowledge of bacteriology, but simply a knowledge of arithmetic as set forth in this question, I would say that the suppositions advanced in this question indicate that the longevity of the bacillus prodigiosus, and of the typhoid bacillus as compared with it, is so extremely slight as to make the probability of a germ of this character being able to survive a passage from the Drainage Canal to Grafton so remote as to be entirely unworthy of consideration. This conclusion depends upon certain calculations which I have made and which I will present. As the various data are given in terms of the metric system, it is necessary to make certain

reductions, in order to be able to reach a proper comparison. First, it is necessary to determine the concentration of the germs in the canal water at the time when they were dumped from the barrels as supposed in the question. At this period the flow in the canal was almost exactly 235,000 cubic feet per minute, which I have reduced to liters by use of the factor 28.3 liters per cubic foot, which is almost the exact factor, giving 6,650,000 liters, very nearly, per minute. Reducing this number of minutes to hours, I find that for four hours, or 240 minutes, assumed to be consumed in this addition of the bacteria to the water, a volume of water flowed equivalent to 1,596,000,000 liters, or approximately 1,600,000,000 liters. As the calculations are finally based on the cubic centimeter rather than the liter, I have reduced this volume to cubic centimeters by multiplying by one thousand, giving as the volume of this water in cubic centimeters, into which the substance from the barrels is dumped, 1,600,000,000,000, or, expressed most accurately in the method now common among mathematicians, 1.6×10^{12}. This is the flow of the canal in cubic centimeters in four hours. I will say for the purposes of comparison it makes no difference whether we assume four hours or eight hours, as the same factor enters late in the calculation at the mouth of the river. We have next to consider from the assumptions of the question the number of bacteria mixed with this volume. One hundred and seven barrels, of forty gallons each, gives the amount of 4,280 gallons, which, when reduced to liters, give us something over 16,000 liters, 16,017 and more liters, but in round numbers I will use 16,000 liters or 16,000,000 centimeters. The number of bacteria per cubic centimeter, according to the assumption of the question, was 1,000,000,000. The total number of bacteria then discharged would be the product of 1,000,000,000 per cubic centimeter, by the number of cubic centimeters, or 16,000,000 multiplied by 1,000,000,000, which, multiplied out, gives us the number of 16,000,000,000,000,000, or more accurately or definitely expressed, 1.6^{16}. We have, therefore, as the number of bacteria following the assumption of the question, which must

have been thrown into the Canal, 1.6^{18}, as given. As the number of cubic centimeters into which this number was thrown was given as 1.6^{18}, the quotient of one of these by the other gives the concentration of ten at the fourth power, or ten thousand bacteria to the cubic centimeter, on the assumption that the mixing or dumping took place through a period of four hours. We have, therefore, as concentration, ten thousand to the cubic centimeter. Now, supposing this wedge of water to pass down the river absolutely unchanged, and supposing further that no increase or decrease in this number of bacteria should follow by death or by any other means, it is simply a statement of fact to say that we should find ten thousand per cubic centimeter at some corresponding time, in some part of the river below, but admitting the fact that a change by dilution follows by taking up the water of the tributaries, and through the uneven flow of the water, the particles moving more rapidly in the center than along the sides of the stream, a certain dilution must be calculated, must be admitted as taking place in this volume. From the fact that these samples were all found within a four-day period, or rather these bacteria were all found in samples collected in a period of four days, as presented in the question, I have calculated this original volume of water as diluted with the volume of water which flows at the mouth of the river in a period of four days. On that assumption, a number of at least 200 should be found per cubic centimeter, for each cubic centimeter examined, on the assumption that no death or loss of these bacteria takes place anywhere in the course. As a matter of fact, not twenty were found in one cubic centimeter, but a very large number of examinations had to be made to find a cubic centimeter in which there was one contained. It is evident that an enormous destruction of these organisms must take place between the point at which the bacteria were thrown in and the mouth of the river where the examinations were made. The actual finding is not over one ten-thousandth of what should be expected from 107 barrels on the assumption that these organisms did not die out; that is, we find less than one ten-

thousandth of the expected amount. If we consider a number less than 107 barrels as added, one barrel for example, the probability of any organism of this character reaching the mouth of the Illinois River, is less than one chance in 1,000,000. If we consider one barrel, or one one-hundredth of a barrel as added, the chance of one of these organisms reaching the mouth of the river and being found in a cubic centimeter becomes correspondingly reduced. Therefore, without involving any question of bacteriology, but simply a question of calculation, it is evident that the probabilities of any number of bacteria in a given small volume, reaching the mouth of the Illinois River, is extremely remote and not one which can be practically or seriously considered. (4258-4260.)

Professor Robert Zeit, on page 4478, stated in answer to a similar hypothetical question as that put to Professor Long: "In the second place, the great numbers that were poured into the canal and the practical absence of them afterwards would only illustrate what the self-purification of rivers means, because this germ grows best at room temperature. It would, perhaps, not die as easily in water as a typhoid bacillus, because it could probably exist better than a typhoid bacillus under those conditions; and I think it would prove that if it is true that the prodigiosus disappears under such conditions, that it would be much more true of the typhoid bacillus."

Professor H. L. Russell, in response to a similar hypothetical question, stated, on page 6474, as follows: "Taking into consideration the assumptions as indicated in the question, and also considering the question in the light of all the knowledge which I possess with reference to the distribution of the organism known as bacillus prodigiosus under natural and normal conditions, my opinion is that this experiment does not in any way throw any light on the matter of the probable longevity of the typhoid bacillus as measured by the longevity of the bacillus prodigiosus, and the assumptions mentioned in the question propounded, leads me to believe it is highly improbable that the organisms reported to have been found on the 4th, 5th

and 8th of December at the intake tower, Chain of Rocks, on the 6th and 7th of December, were the same or derived from the organisms which were placed in the waters of the Chicago Drainage Canal at Lemont on the 6th day of November.

"This conclusion is based upon the fact that a series of examinations made on the samples taken from the water of the Illinois River at Lockport, Joliet, Peoria and Grafton between the 7th of November and December 15th, amounting in all to 1,752, and also samples taken from the intake tower at the Chain of Rocks, at the laboratory tap in the City of St. Louis, between November 20th and March 1st, amounting in all to 3,120, failed to reveal the presence of the bacillus prodigiosus until twenty-eight days had elapsed from the time the culture were placed in the river at Lemont.

"If the organisms which were reported to have been isolated from the waters of the Illinois River at Grafton and the Mississippi at the Chain of Rocks had been the same or the progeny of the same as those which were deposited in the Chicago Drainage Canal at Lemont, it would have been natural to expect that in the numerous preceding analyses which had been made, organisms of this species would have been found, as there is reason to believe that the flow of water from Lemont through the Illinois River to the City of St. Louis would not have consumed a period of twenty-eight days.

"Assuming that the organisms reported as bacillus prodigiosus, which were found on December 4th, 5th and 8th, at the intake tower, Chain of Rocks, and December 6th and 7th at Grafton, were organisms derived from other sources than those due to the depositing of 107 barrels of culture of the bacillus deposited on November 6th in the river, and assuming that hourly and daily samples were made at these stations along the course of the Illinois River from Lockport to Grafton, and from the waters of the Mississippi River at St. Louis, said analyses amounting in all to 5,304, and assuming that in no case were any organisms belonging to the bacillus prodigiosus found in any of these stations, with the exception of the three

germs found at the intake tower, Chain of Rocks, December 4-8, and two organisms found in the Illinois River at Grafton on December 6th and 7th, after a period of twenty-eight days after those 107 barrels of culture had been placed in the Illinois River at Lemont, and assuming the well known fact that the bacillus prodigiosus is a saprophytic organism, capable of living in the water under natural conditions a longer period of time than active, vigorous, non-spore bearing parasitic bacteria, such as the bacteria of typhoid fever, it is my opinion that the result of the above experiment show that it is highly probable that the saprophytic bacillus prodigiosus had been destroyed in the waters of the Illinois River during the course of its flow from Lemont to Grafton and the City of St. Louis, and, therefore, assuming that such were the case, it would be much more probable that the more delicate and easily affected organism of typhoid fever, entering the waters of the Drainage Canal of Chicago, from the sewers of Chicago, would not have survived a journey down the Illinois River and the Mississippi River to the intake tower, Chain of Rocks, at St. Louis." (6476.)

Professor E. G. Smith was asked a similar question and replied in substance (6749): "The longevity of the bacillus prodigiosus is not necessarily a measure of the longevity of the typhoid bacillus. The bacillus prodigiosus is known to flourish at ordinary temperature, while there is no evidence that the typhoid fever organism can flourish or develop in water.

"If this organism had remained in the water for any length of time, the observers at Joliet and Peoria would have found them, while the results show that they were not found above Grafton. Even if they had been found in constantly diminishing numbers, it would be reasonable to assume that if those organisms were the ones that actually made their way down the river, they would have been found in larger numbers in the samples taken at Joliet and Peoria than at Grafton. As a matter of fact, there is no record that they were ever found at the two stations on the upper river. It seems to me to be a

contribution to the study of the self-purification of that stream. It is an evidence for the stream being rid from them rather than anything else."

Professor W. P. Mason stated, in regard to this experiment, on page 6909: "It is my opinion that in view of the large number of the bacillus prodigiosus introduced and the small number found, the results of that experiment show a very considerable death rate of the bacillus prodigiosus, and, by inference at least, as large a death rate of the bacillus of typhoid fever under the same circumstances."

Professor E. O. Jordan, who considered this experiment, and who discovered a bacillus prodigiosus in the Illinois River at Morris in 1899, as above referred to, testified in regard to this experiment as follows: "In my opinion, this experiment sheds a certain amount of light on the probable longevity of a typhoid bacillus under the conditions as stated. This is true for the reason that the relatively insignificant findings of bacillus prodigiosus, assuming identification to be correct, indicate that this organism, while a fairly hardy saprophytic form, does not live long in the river water, and that the typhoid bacillus, which is beyond doubt a more highly specialized parasitic form than bacillus prodigiosus, would not survive as long as the latter. The experiment, in my judgment, affords strong confirmation of the evidence already derived from a study of the death rate among colon bacilli in the water of the Illinois River. Since bacillus prodigiosus dies off so speedily and in such large numbers, the typhoid bacillus would be less likely to survive exposure to these same conditions."

These answers of witnesses for defendants agree in drawing attention, first, to the fallacy involved in the assumption that the organisms found at Grafton and the Chain of Rocks were the same as those alleged to have been placed in the waters of the Drainage Canal at Lemont; second, to the remarkable and highly significant fact that while hourly examinations were made day and night at Lockport, Joliet and Peoria, points much nearer than Grafton to the place where bacillus prodigiosus is

said to have been deposited, no single case is reported of the finding of this organism at these points in the Desplaines and upper Illinois Rivers. The readily recognizable character of this organism, the feature for which it was especially selected for the purpose of this experiment, makes it appear very improbable that if these bacteria had survived to reach Joliet or Peoria, they would have been missed by the observers stationed at these points primarily with the view of discovering the presence and numbers of this species that floated past in the river water.

Taken at its face value, therefore, this bacillus prodigiosus experiment represents one of the most striking and convincing demonstrations of the bacterial self-purification of streams that has ever been afforded.

Summing up the conclusions to be drawn from these three experiments as hereinbefore detailed, and taking into consideration that this organism was incidentally found in the waters of the Illinois River by Professor Jordan in 1899, and has been found in the waters of the western country by other investigators who were not concerned in any way with this experiment, together with the fact disclosed by the first and second deposits of these germs in the Mississippi, when the organism was discovered twenty-eight and thirty-four days after it was deposited in the Mississippi River at Grafton; also considering the fact that none of these organisms were discovered at Lockport, Joliet or at Peoria—all the facts and circumstances connected with these three experiments show that the organisms that were discovered in the Mississippi River by Dr. Ravold during each of these experiments were organisms whose natural habitat was the Mississippi River, and they were not the organisms that were deposited in the broth culture introduced into these waters by this witness.

Longevity of the Typhoid Bacillus.

It is a fact, all but universally recognized, that typhoid bacilli suspended in water or sewage in ordinary glass bottles

in a laboratory are under more favorable conditions than they are in a flowing stream. This statement is supported by all the bacteriologists who have testified in this case, with the exception of Dr. Ravold. (478-479.)

This is due to the fact that, as shown by the experiments of Professor Jordan, and by those of European investigators cited in his testimony (6159-61), substances are dissolved from ordinary glass that prolong the life of the typhoid bacillus. These experiments have never been questioned.

This recent discovery of the influence of ordinary glass containers in prolonging the life of the typhoid bacillus has vitiated the observations of the earlier observers upon the longevity of this microbe in glass bottle laboratory experiments. With a view of removing objections due to the character of the container, a series of experiments was devised for determining the life of a typhoid bacillus under normal conditions of life, temperature, etc. These experiments were carried out on a large scale by three eminent bacteriologists for defendants, Professors Jordan, Zeit and Russell, and their testimony, as given in full in the record, constitutes the most important contribution yet made to the investigation of the longevity of the typhoid bacillus in water. This is due to the fact that these extended experiments were carried out under actual conditions of temperature, nature of water in which the typhoid bacilli were placed, and other natural influences that might be expected to affect the longevity of the microbe. The most important feature of these experiments, however, was the avoidance of the use of glass bottles. In their place parchment and celloidin sacs were employed.

These sacs were made of parchment tubing about two inches in diameter and were prepared from heavy parchment paper, such as is used in chemical work for osmotic experiments. The sacs were fastened to a piece of glass tubing some six inches in length and were firmly tied to this and sealed with a mixture of tallow and resin. The sac was weighted so as to swing freely in the water when filled with sewage. These sacs were

suspended in the water in a frame-work covered with a wire screen, which permitted free circulation of the water. This frame was made of fine strips of wood and was four feet long and three feet wide and three and one-half feet deep. The bottom, top and lower five-sixths of the sides and ends of this frame were covered with wire screen. The upper six inches of the sides and ends of the box, and the sides and ends of the cover, six inches deep, were of one inch pine fencing. The top opened with a hinge and was fastened in place by a hasp and padlock. The box was balanced in such a way that it floated with the water level up to the height of the lower margin of the upper solid portion of the body. The part above the water was thus of boards and served to break the waves from passing vessels or wind. At Robey Street the box was set between the timbers of a large floating frame. The wire covering the box had two and one-half meshes to the inch. At Lockport the box was fastened to the floating dock near the Bear Trap Dam. The wire covering the box is of a three-quarter inch mesh. At both of these places the floats were situated in such a way as not to prevent free circulation of water through the large wire meshes. Inside the box were several coarse strips about an inch above the water level in which slots were cut in intervals of about three inches to receive the glass ends of the tubes. Opposite each slot was a staple through which was passed a cord attached to the tube, which was thus securely held in place. To guard further against the tipping of the tubes, small slips were fastened across the slots to prevent effectually the accidental removing of the sacs. These boxes were fastened with a padlock, and throughout the experiments the key to both boxes was in the possession of the chief assistant. The lower end of the parchment sac was sealed. It was rolled up tightly and wrapped with thread. Both the upper and lower joints were saturated with a mixture of resin and tallow. The capacity of the sacs ranged from seven hundred to eight hundred cubic centimeters. The sacs were tested for cracks or punctures before leaving the

laboratory and then again when they were filled in the field. To the lower end of each sac a small weight was attached, which served to keep the sac in an upright position in the water. (6181-2.)

Similar boxes and sacs were used in the experiment carried out in the Chicago River and the Illinois River above Peoria. In addition to the parchment sacs just described, celloidin sacs, often used for the same purpose, were also used. (6235, 6421-2, 6499, 6501.)

With the aim of making the investigation as exhaustive as possible, agar blocks, in which were placed typhoid bacilli, were also employed. The agar allows diffusion to take place, and thus typhoid bacilli in the interior of these blocks would be in a measure exposed to the action of the diffusible substances present in the river water. (6516.)

It was considered by these bacteriologists important to obtain typhoid bacilli which had not been weakened by artificial cultivation, and therefore cultures freshly isolated from the bodies of typhoid fever patients were used for the purpose of inoculating these sacs. (6183.)

One of these typhoid bacilli was obtained from the blood of a patient, one from the urine of a patient, and one from the feces of a patient. The virulence of these organisms is shown by the fact that in two instances the outcome of the case was fatal. The aim of isolating these cultures in a fresh condition from the bodies of patients was to obtain the maximum degree of vitality and virulence, thus making the outcome of the experiment, whatever it might be, as valuable as possible from a scientific point of view, and as conclusive as possible from the sanitary side. (6156.)

Furthermore, in order to simulate natural conditions so far as possible, typhoid bacilli were introduced into the sacs in the urine of typhoid fever patients, just as they might conceivably have passed into the sewers of Chicago.

In Professor Jordan's experiments in the Drainage Canal, thirty-eight sacs were used, each one of which was closely fol-

lowed for a number of days, virtually amounting to thirty-eight separate experiments. Professor Zeit used some twenty-five sacs in his experiments in the Chicago River. (6443.) In the Illinois River, at Peoria, fifteen sacs were used by Professor Russell. (6503.)

In addition to these, four experiments with agar blocks were made. (6517.) In all cases control or uninoculated sacs were used for the purpose of determining whether the sacs remained intact throughout the experiment; and whether in other ways conditions were constant and normal.

The parchment and celloidin sacs used in these experiments permit the passage of certain substances in solution, but do not allow bacteria to pass through their walls. They are so-called dialyzing membranes, which permit the ingress and egress of certain substances in solution, according to the physical laws of osmosis. In these sacs, therefore, bacteria are subjected to the action of the same substances in solution to which they would be exposed if they were moving freely in the waters of the river or Drainage Canal.

Dr. Ravold's theory (791) that the enzymes and toxins produced by saprophytic bacteria in sewage act not only deleteriously upon saprophites, but upon the pathogenic micro-organisms, in such an experiment as the one under discussion, is afforded full opportunity for realization, the typhoid bacilli in the sacs being freely subjected to the action of such substances as were formed by bacteria in the sacs as well as those that could pass through the membrane from the fluid outside.

Dr. Herbert E. Smith, who testified for complainant in rebuttal, undertook to criticise the technique of the experiment performed by Professors Jordan, Zeit and Russell, in spite of the fact that he acknowledged that he had never himself performed any experiments upon the longevity of typhoid bacillus, either in the laboratory or in a flowing stream. (7747.)

Professor Smith's qualifications for passing judgment upon the technique of this experiment may be inferred from his statement that the parchment sacs permit dialysis, while celloidin

does not. (7750.) "There is no particular criticism that occurs to my mind as comparing the use of celloidin and parchment. Of course, there was a difference in the fact that one permits of dialysis, while the celloidin does not."

"It is a fact that sacs made of celloidin have long been used in bacteriological work and have been found particularly useful in performing experiments upon animals. Small celloidin sacs filled with a fluid culture of bacteria, have been introduced into the bodies of animals under aseptic conditions. The advantage of the celloidin sac, used in this way, is that it permits the soluble products and toxins generated by the bacteria to pass through the wall of the sac while confining the bacteria themselves and not allowing them to spread through the body. This method has shed a good deal of light upon the action of the poisonous products of bacteria, as distinguished from the changes produced in the body by the presence of bacteria themselves." (See Jordan, 6187.)

Professor Zeit has also testified to the common use of celloidin sacs in bacteriological experiments.

"The celloidin sacs have been proved reliable in bacteriological animal experiments, in which, for instance, tetanus bacilli would be placed in a closed celloidin sac and inserted within the abdomen of an animal. The animal dies of tetanus, although the bacteria remained in the sac. In that way bacteriologists have often studied the effect of soluble toxins, eliminating any influence that the germ itself might have." (Zeit, (6446.)

In view of the fact that celloidin sacs have been for years extensively and commonly used for bacteriological investigations, the statement of Professor Smith that they do not permit dialysis seems highly remarkable, and impairs the force of any technical criticism that he might make of the experiment here discussed.

One other witness testifying in rebuttal for complainant (see Sedgwick, 7960-1), while bearing testimony to the importance of these experiments, nevertheless criticises them on the

basis that they are not in harmony with the results obtained by some previous experimenters.

"Furthermore, the results of these experiments, broadly speaking, indicate a considerably shorter period of life for the typhoid fever germs in sewage or water than has been found by the majority of previous investigators." (Sedgwick, 7961.)

As already pointed out, it is fallacious and misleading to compare the result obtained by "previous investigators" in glass bottle experiments with the results obtained in dialyzable parchment and celloidin sacs under natural conditions. The criticism of Professor Sedgwick is really a tribute to the accuracy and value of the method employed by Professors Jordan, Zeit and Russell.

The only other criticism made by Professor Sedgwick is a curious one, namely, that the experiments were carried on for the most part in cold weather. It is a well established fact in bacteriology, and no witness in this case has questioned the fact, that a low temperature is favorable to the continued longevity of all bacteria, including the typhoid bacillus, so that in this respect the experiments in question were conducted at a time of year when conditions for continued longevity on the part of the typhoid bacillus were most favorable.

When Professor Sedgwick appeared in this case as a witness in regard to the so-called Washington epidemic, and stated that he understood that he was acting for and in behalf of the State of Missouri, in an advisory capacity in this lawsuit as an expert (2767), defendants did not expect his reappearance in the capacity of an advocate; but he rose to that dignity when he stated on his third appearance (7662), in attempting to discredit this experiment: "I believe, therefore, that while the experiments of the experts for the defense are interesting, ingenious and important in the science of bacteriology, they should not be allowed to have too much weight in determining the issues in this case." (7962.)

Defendants are at a loss to understand how so eminent a sanitarian as Professor Sedgwick could allow himself, while on

the witness stand, to express an opinion as to the weight to be attached to these experiments in determining the issues in this case, as defendants believed that he was called to act in an impartial capacity as a man of science, and give his opinion as such, but not to advance ideas upon the weight of testimony.

Taking into account all the facts regarding the extent, duration and thoroughness of these experiments, it is evident that no such elaborate studies of the longevity of typhoid bacillus in water had ever previously been made. It is obvious, too, that whether or not the conditions of this experiment are precisely identical with those that might obtain in nature, they at any rate conform more closely to natural conditions than any experiment heretofore carried out.

Perhaps the most serious criticism that has been made is that the typhoid bacilli imprisoned in these sacs are not exposed to precisely the same influences that they would be if they were swept down stream in the course of a constantly changing flow, and under conditions that vary more or less from moment to moment. So far as this case is concerned, however, this criticism loses all its force, since complainant's witnesses have repeatedly urged that typhoid bacilli can remain alive in the sediment of streams for a considerable period. It is plain that such bacilli are anchored in the bed of a stream in precisely similar fashion and are exposed to the same variety of changes as are those in the sacs that were placed in the stream at fixed points.

Professor Sedgwick (7961) has stated that the experiments in question failed to duplicate the various conditions of a running stream in that the germs "were anchored, so to speak, at fixed points, instead of being allowed to float down the stream with the particular body of water. Any one can readily see that this is an unnatural condition, especially in the case of the Drainage Canal and the Chicago and Illinois Rivers, for the reason that the chemical composition of these bodies of sewage and water is subject to frequent changes. * * * For this reason, sacs or blocks at anchor are probably exposed to a greater variety of changes than they would be exposed to if

they were to float down the stream with one particular body of water." (7962.)

These statements of Professor Sedgwick apply quite as well to germs deposited in the sediment of a stream, and since Professor Sedgwick and other witnesess for complainant have laid great stress upon the life of germs in sediment, it is clear that the conditions of bacteria in these anchored sacs are just as natural as that of any germs anchored in sediment. It must either be admitted, then, that, as urged by Professor Sedgwick, the germs in the sediment are exposed to more injurious influences than those floating with the current, or this objection to the experiment on the ground that the germs were not borne downward by the current must be dropped. The argument cuts both ways.

It may be pointed out in addition that the bacteriologists who conducted this extensive experiment attempted to forestall criticism on this point in planning their experiment. Sacs of typhoid bacteria were suspended in the water of Lake Michigan, in the water of the Chicago River, in the water of the Drainage Canal at its point of origin, at Robey Street, in the water of the Drainage Canal at Lockport, twenty-nine miles below, and in the water of the Illinois River at Averyville, just above Peoria. Examination of the tables of chemical analyses of water from these points will suffice to show a very considerable range in the composition and character of the fluid in which the typhoid bacilli were suspended. By following out this carefully planned distribution, the objection raised, although inconsistently, by complainant's witnesses, is shown to have little force, even as a scientific argument.

The outcome of these experiments is certainly worthy of all consideration. The evidence shows that every attempt was made to discover typhoid bacilli in the contents of these sacs; that the most modern and approved bacteriological methods were employed in the search for the typhoid bacilli and that these methods were carefully tested and controlled by the observers, with a view to making the experiment as exhaustive

and conclusive as possible. The utmost pains was taken to secure skilled and expert assistants among the various subordinate workers engaged in the work. On this point the evidence shows that not a step in the procedure was entrusted to unskilled or ignorant hands, but that for even the minor parts of the work bacteriologists of repute, and in some cases of national reputation, were employed. The methods used were controlled at every point, and the trivial character of all of the objections brought forward by complainant's witnesses is sufficient to indicate their inability to find any serious flaw in the experimental data. There is no escape from the conclusion that the vast majority of typhoid bacilli introduced into these sacs at various points perished within twenty-four to forty-eight hours after their introduction. A special case, selected from the experiments of Professor Jordan, may illustrate some of these points. (6232.) Into a sac, designated as N1, and filled with water taken from the Drainage Canal at North Robey Street, typhoid bacilli were introduced in such number that each c. c. of the water contained 857,000 typhoid bacilli. The accuracy of the methods employed may be gathered from the fact that of fifty-seven colonies developing from one one-hundredths of a c. c. (this amount of water contained 8,570 typhoid bacilli just after inoculation) selected for study twenty-eight hours after inoculation as being nearest in appearance to typhoid colonies, forty-three proved to be genuine typhoid bacilli. This result shows that the method employed is adequate for detecting typhoid bacilli in the presence of a large number of sewage bacteria, and that when properly employed it will reveal the presence of even a few typhoid bacilli, mingled with a multitude of other forms.

Of twenty-four colonies in ten times the quantity of water (one-tenth of a c. c.), examined after two days (forty-eight hours), two proved to be typhoid; and thereafter not a single typhoid bacillus was found, although the examinations were continued with the same rigor for ten days, and all the suspicious typhoid like colonies developing from one c. c. of water were examined on several occasions.

It will be superfluous here to enter further into the details of the individual experiments conducted by Professors Jordan, Zeit and Russell, since they are given clearly and fully in the evidence. Summarizing all these experiments, it appears incontrovertibly that the enormous majority of typhoid bacilli introduced into the waters of Lake Michigan, the Chicago River, into the Drainage Canal at Robey Street and at Lockport, and into the Illinois River at Averyville, perished within forty-eight hours after their introduction. Bacteriologists are obliged to assume, therefore, that under ordinary conditions typhoid bacilli introduced into the waters of the Drainage Canal, under natural conditions, would not and do not live in that situation longer than four days. (6239.)

In one isolated instance reported by Professor Jordan, three colonies of typhoid bacilli appeared in water taken from a sac after an interval of eight days, during which no typhoid bacilli had been taken, although a large number of colonies were examined. The most reasonable explanation seemed to him to be that at the time when the contents of the sac were heavily infected with typhoid bacilli, some concrete particle in the sewage to which typhoid bacilli were adhering was deposited during the process of tilting and agitation previously referred to and became dried upon the wall of the sac above the water line. Under these conditions, it was his opinion that the typhoid bacillus might remain alive for some time. Such a dried particle containing living typhoid bacilli might conceivably be washed off from the place where it had lodged. Other reasons for this explanation are given by Professor Jordan in his testimony. (6240.) He states, moreover, that this isolated case was due to an accident occurring under the conditions in which the experiment was conducted, and did not indicate that typhoid bacilli would survive as long as ten days in the water of the Drainage Canal itself. (6240.)

It should be mentioned that this explanation was considered by Professor Jordan, and the other scientific witnesses testifying in this case, to be the most reasonable one, and that this

accidental and exceptional occurrence had no bearing upon the main experiment, and the conclusions to be drawn from it. It is significant that this position of Professor Jordan was apparently concurred in by the witnesses for the complainant, otherwise they would have offered some evidence showing the fallacy of this explanation.

The results of this experiment, and the weight to be attached to it, are best determined by giving the opinions of the men who made it. Professor Russell, in answer to the question, "What conclusion do you draw as to the longevity of the typhoid bacillus in the waters of the Illinois River, based upon this experiment?" stated, "From experiments which I have actually made when freshly isolated cultures of bacillus typhosus were exposed in permeable sacs in varying numbers, so that the germ content of the water used in the ratio of 100 to 1 or more, and where the organisms were destroyed in the course of about three days, with one possible exception, and that if this was the condition which was obtained under the conditions in which the experiment was made, when the effect of other environmental factors were excluded, such as the influence which would come from sedimentation, dilution, influence of light, vital concurrence with green plant form, which might be found in the waters of such river, I should certainly consider that the life of the typhoid organisms, when subjected to the more severe conditions which obtain in the waters of the Illinois River itself than was the case in the experiments with the parchment sacs, that it certainly would be no longer in the waters of the Illinois River, and in all probability would be shorter, hence I would conclude from the foregoing data that the vitality of the typhoid organism would not in any case be maintained for more than a period of a very few days, three or four at the outside.

"Q. What, in your opinion, based upon all the knowledge which you possess in regard to typhoid germs, would be the fate of the typhoid bacillus passing from the sewers of Chicago into the Chicago River and thence into the Drainage Canal, and down the Desplaines and the Illinois Rivers?

"A. In view of the facts that have been obtained in the experiments which have been conducted conjointly by Professors Jordan, Zeit and myself, and in view of my knowledge of the conditions which would obtain where the sewage of Chicago was allowed to flow into the Chicago River, thence into the Drainage Canal and down the Desplaines and Illinois Rivers, and in view of the fact that the experimental evidence as to the vitality of the typhoid organism, when exposed to the waters as found in the Chicago River, the Drainage Canal and the Illinois River, under the conditions of the experiment previously described, and in view of the fact that in my judgment typhoid organisms so deposited in the Chicago River, Drainage Canal and Illinois Rivers, would be subjected to even more detrimental conditions than did exist under the conditions as recorded in these experiments, and in view of the fact that the sewage of Chicago, deposited in the Chicago River and finding its way to the Drainage Canal, and down the Desplaines and Illinois Rivers, would require a much longer period of time to pass from the City of Chicago down the Desplaines and Illinois Rivers than is required to kill typhoid organisms when placed in such an environment as would exist under these conditions.

"I am of the opinion that typhoid organisms finding their way through the sewers of Chicago into the Chicago River, and thence into the Drainage Canal, down the Desplaines and into the Illinois River, would be destroyed before such water had passed the course of the Illinois River.

"Q. From a scientific standpoint, what value do you attach to this experiment, as showing the longevity of a typhoid bacillus in polluted waters?

"A. In comparing numerous experiments which were made under varying conditions as to the longevity of the typhoid organism in the waters of the Drainage Canal and the Illinois River, with the experiments which have been previously reported by other investigators on the typhoid organisms exposed under various conditions, I am of the opinion that the conditions under which the experiments now reported were

made approach more nearly to the natural conditions to which the typhoid fever organism would be subjected when exposed in the water of the flowing stream, such as would be the case in the Illinois River in passing from the City of Chicago down the said river, and therefore, from a scientific standpoint, a greater value is to be attached to the important results of this experiment made by Professors Jordan, Zeit and myself, independently, but concurrently, than to the conclusions which have been previously drawn from the experiments of other investigators, and that the results of such experiments show that the longevity of the typhoid bacillus is less in polluted waters than in waters of a pure class.

"Q. Does this experiment shed any light upon the longevity of the typhoid bacillus in the sediment of polluted streams?

"A. Pathogenic bacteria, exposed in the sediment of polluted streams, are brought in contact with even a larger number of bacterial organisms than would be the case if they were exposed to superincumbent water masses, and therefore presumably in contact with the increasing amounts of metabolic products, and inasmuch as the pore spaces between the particles of sediment are entirely filled with water, it is my opinion that the conditions which would obtain in the sediment of polluted streams would certainly be not less prejudicial than those which would be found in the water of the stream itself, and therefore I would consider that if the longevity of the typhoid bacillus be impaired by the action of sewage and the water bacteria of a polluted stream, that at least the same, if not a greater, effect would be produced if the typhoid organism was in contact with these bacteria and the products of their growth in the sediment of such a stream.

"Q. Had this experiment been conducted in warm weather, instead of the season that it was, what effect, in your opinion, would be manifested in the results?

"A. It is a well recognized fact in bacteriology that the vitality of various organisms, particularly those of a pathogenic class which find unsuitable conditions for their development in

the outside environment, is profoundly affected by temperature of their surroundings, and the results of many tests upon this point indicate that the vitality of such organisms is retained for a longer period of time during those periods when the temperature is low than is the case when higher temperature prevails.

"The reason for this undoubtedly lies in the fact that the characteristic changes which occur in the life history of any organism go on more rapidly with an acceleration in temperature, and, therefore, if this experiment had been conducted at those seasons of the year when the metabolism of all organisms is at its highest during the period of highest temperature, the results of the experiments undoubtedly would have shown that the vitality of the organisms would not have been as long as was the case when the temperature under which the experiments were conducted was materially lower than those which would have prevailed in the height of summer." (See 6520 to 6524.)

Professor Zeit testified as follows:

"Q. How near, in your opinion, does the experiment made by you yourself simulate natural conditions?

"A. The conditions are as close to natural conditions as it is possible to make them.

"Q. Were the conditions of the experiment which you have introduced more or less favorable to the longevity of the typhoid bacillus than the natural conditions of the water in which the experiment was made would be?

"A. I do not think that there is much difference between the conditions in the sac and the conditions outside.

"Q. What reasons have you for supposing that the conditions described in your experiment closely simulate natural conditions?

"A. Because the surroundings of the typhoid bacillus in the river are the same as those in the sac, by osmosis of the different fluids, and, as I have already stated before, the principal cause of the death of the typhoid bacillus in water is evi-

dently the presence of some saprophytic products which are outside of the sac, just in as large a quantity as inside of the sac, and if there existed any difference these differences would be quickly equalized by osmosis.

"Q. Professor, does this experiment which you have made and introduced, furnish you with any basis for an opinion as to the life of the typhoid bacillus in the waters of the Chicago River and Drainage Canal and Illinois River?

"A. Yes, sir. As a result of the experiments which have been made by all of us—Professor Jordan, Professor Russell and myself—I am of the opinion that typhoid bacilli cannot live in the Drainage Canal or the Chicago River or the Illinois River for more than three days.

"Q. What is your opinion, based upon all the knowledge that you possess in regard to this experiment, and other experiments made by you, as to whether the typhoid bacillus coming from the sewers of Chicago and entering the Drainage Canal, and from thence into the Illinois River, could survive the journey from Chicago to St. Louis, a distance of 357 miles, and be a danger and a menace to the inhabitants of St. Louis, using the waters of the Mississippi River at the St. Louis intake, or the residents of Missouri using the waters of the Mississippi River, as it passes along the eastern shore of the State of Missouri, for domestic and drinking purposes?

"A. It is my opinion that it offers absolutely no danger to the citizens of St. Louis and that no typhoid bacillus coming from the sewers of Chicago will live to reach there." (See Zeit, 6436-37.)

Professor E. O. Jordan states as follows:

"Q. From the results of these experiments, what conclusion do you draw as to the longevity of a typhoid bacillus in the water of Lake Michigan?

"A. It was found by actual experiment, under conditions which I believe to simulate closely those in nature that the typhoid bacillus, introduced into unsterilized Lake Michigan water, was recovered four days after inoculation, and was

not found in subsequent examinations made up to the fifteenth day. It is probable that specially resistant individual cells might survive longer than appeared to be the case in the experiment described in my testimony, but in my opinion even such highly resistant individuals, if they did exist, would not live more than about twice as long as the time recorded in these experiments. So that I conclude that eight to ten days would be a maximum period of longevity for the typhoid bacillus in the water of Lake Michigan, under natural conditions.

"Q. From the result of these experiments, what conclusion do you draw as to the longevity of the typhoid bacillus in the water of the Drainage Canal?

"A. These experiments, of which a large number were made with varying numbers of typhoid bacilli introduced directly into the water of the Drainage Canal, gave generally uniform results. It was not difficult to discover typhoid bacilli during the first two days. Later than that, they were never found, either at Lockport or at Robey street, with one exception. In this anomalous case, three typhoid bacilli were isolated on the tenth day from a single plate in a single sac.

"Taking into consideration all of the experiments made in the waters of the Drainage Canal, and assuming, as before, that specially resistant individual cells might exist, which would live twice as long as those found, it is my opinion that typhoid bacilli introduced into the waters of the Drainage Canal under natural conditions would not and do not live in that situation longer than four days.

"Q. From the result of these experiments, what conclusion do you draw as to the longevity of typhoid bacilli in the water of the Illinois River?

"A. Remembering that the upper stretches of the Illinois River are highly polluted with sewage and that considerable additions of sewage are made to the Illinois River at points along its course, I do not believe that bacilli introduced into the Desplaines or upper portion of the Illinois River would live under natural conditions more than five or six days.

"Q. What, in your opinion, would be the fate of a typhoid bacillus passing from the sewers of Chicago into the Chicago River and thence into the Drainage Canal and down the Desplaines and Illinois Rivers?

"A. It is my opinion that a typhoid bacillus, discharged from the body of a typhoid patient in Chicago, and assuming that such discharges were not disinfected, so that the bacillus could pass into the sewers of Chicago, and thence into the Chicago River and Drainage Canal, might live as long as three or four days after leaving the body of the patient.

"From what I know of the rate of flow in the Drainage Canal and in the Desplaines and upper Illinois Rivers, in my judgment such a typhoid bacillus would perish long before Averyville was reached, even at a period of low temperature and high water.

"Q. From a scientific standpoint, what value do you attach to this experiment as showing the longevity of a typhoid bacillus in polluted water?

"A. I regard the experiment as described as shedding a great deal of light upon the life of a typhoid bacillus under natural conditions.

"The results, in my opinion, show quite conclusively that if any typhoid bacilli survive later than forty-eight hours after they have been introduced into the highly polluted waters of the Drainage Canal, they must be highly resistant and very exceptional individuals.

"Q. Does the experiment shed any light upon the longevity of the typhoid bacillus in the sediment of polluted streams?

"A. I think it does in this way, that although some sedimentation of the suspended matter occurs in these sacs, the tilting and agitating of these sacs each time before the sample was taken led to a thorough mixing of the suspended and sedimented particles. I found no reason for believing that bacilli lived any longer in the sediment of such sacs than freely suspended in the fluid." (See 6238 to 6241.)

In addition to this experiment which has just been detailed,

Mr. John W. Hill, of Philadelphia, introduced in evidence in this case an experiment made by him upon the longevity of the typhoid bacillus. The object of this experiment was to ascertain what effect chlorine had upon the typhoid germs. Mr. Hill states, on page 7509:

"I have, in connection with the work now going on in Philadelphia, made an experiment upon the longevity of the typhoid bacillus. Two years ago last fall, with a view to determining what, if any, influence the amount of chlorine in the Delaware River might have on the longevity of this organism, at that time I outlined plans that were subsequently put into effect by Mr. Copeland, bacteriologist in charge of the technical laboratory, to show how long the typhoid organism and the colon bacillus would live in unsterilized Delaware River water, with the quantities of chlorine varying from 25 points per million to 300 parts per million, and this test, which extended over a number of days, in fact over a number of weeks, revealed the fact that the amount of salt in the Delaware River water had little or no influence upon the longevity of the organism, and that its life history was limited to from five to eight days under the most favorable conditions. It also revealed the fact that the colon bacillus would live longer in the unsterilized Delaware River water with the different degrees of salt than would the typhoid organisms."

The details of this experiment, with a table of bacterial determinations, appear in Mr. Hill's testimony on pages 7510 to 7514, and his application and conclusions based upon the experiment above refererd to as to the longevity of the typhoid germ is expressed in his testimony in part, and is as follows:

"Q. Aside from the question of the longevity of the typhoid germ as affected with the presence of chlorine, does this test afford you any information or a fact upon which to base and predicate an opinion as to the life or longevity of a typhoid in polluted river water?

"A. Yes, sir; it does. In the absence of information to the contrary, I should assume the longevity of the typhoid or-

ganism in lake or river water where the sewage pollution was no less than that of the Delaware River at Torresdale, would be substantially the same as that found here. I give this opinion in view of the fact that the temperature of incubation doubtless would be the same for unsterilized or sterilized water taken from any other suspected source of water supply, and in the case of special information collected at some other point from some other stream or source of water supply, I should be governed, in expressing an opinion on the longevity of the typhoid organism in unsterilized, polluted river or lake water, by the results of the tests made on the Delaware River water at the Torresdale testing station, and the results of tests also made on the Schuylkill River water at the Spring Garden testing station. The tests with the sterilized Schuylkill water being given in the first line of each of the tables, and the next seven are sterilized Delaware River water.

"Q. Why was sterilized water used?

"A. Because it was thought to be more favorable to the growth of the organism than unsterilized water, and because it eliminated the danger of our failure to detect the typhoid organism after a few days of growth, no other organism growing in the water except that due to the inoculation of the test flasks.

"Q. Would this experiment made on sterilized water furnish you with a basis for an opinion as to the longevity of the typhoid germ in the raw water of these rivers?

"A. It would, because such data as has come under my observation indicate that the typhoid organism, or any specific water bacteria, will live longest in sterilized water, due to the fact that sterilization does not remove the food material and possibly increases its availability as proved for the bacteria and such food material is consumed only by the organism with which the experiment is being made.

"Q. What is your opinion, based upon the experiment which you have just introduced in evidence, as to the longevity of the typhoid fever germs in the raw waters of these two rivers at a point where the experiment was made?

"A. I should feel safe in expressing an opinion that the organism would certainly not live longer in the unsterilized than it did in the sterilized water, and probably would have a shorter life history. The greatest length of time that a typhoid fever organism lived, as shown by the tables, is eight days. I should anticipate that its life in the unsterilized water would certainly be no longer than eight days, and probably less than eight days, by reason of the facts stated in answer to a previous question with reference to the influence of sterilized water on the life history of the organism with which it may be inoculated.

"Q. Are the conditions of laboratory experiments more or less favorable than the conditions in nature for the longevity of the typhoid bacillus, in your opinion?

"A. I regard the laboratory test usually made, and certainly all that I have made or caused to be made, as more favorable to the growth of the typhoid organism than it would be in the normal water with which the experiment was being conducted, as the desire is to show the greatest possible longevity under the conditions of the test. This is brought about by maintaining a constant temperature of the flasks in which incubation is being carried on and by observing all other conditions conducive to the maintenance of life of the organism.

"Q. From your knowledge of this organism, what is your opinion as to the longevity of the typhoid bacillus in ordinary river waters which are receiving sewage from urban centers?

"A. I should put the life of the typhoid organism in a sewage polluted river water, under normal conditions which prevails with the majority of the rivers of the United States drawn on as the sources of public water supply, as from five to eight days. I am now referring to the typhoid organism that would come in from a definite point. That organism would probably be not found in the water at the end of five to eight days. It would be rivers where the normal temperatures were about like those of Philadelphia. I would not like to apply that to the St. Lawrence River, for example, because I am not quite

sure about it, but I think the colder the stream the longer the organism would live, and the warmer the stream the quicker it would perish.

"Q. Now, with reference to the degree of pollution; would that have any effect?

"A. Yes, it would. But I am assuming, as a general proposition, that the rivers, when they are the source of public supply, as the Delaware, the Schuylkill, the Merrimac, the Hudson, the Missouri, and the Mississippi, at points of intake for large cities are not largely different, with reference to sewage pollution, that is, it is more intense in some cases than in others, but nevertheless there is a distinctive sewage pollution in all those streams that would have some modifying influence on the longevity of the organism.

"Q. Would the Illinois River be found in the class of rivers which you have referred to in your previous answer?

"A. It would.

"Q. To be specific, what is your opinion as to the longevity of the typhoid fever germ in the waters of the Drainage Canal, the Desplaines and the Illinois Rivers, based upon all the knowledge which you have as to the longevity of the typhoid fever germs in similar waters?

"A. From such information as I have of the bacteriological and chemical contents of the Illinois River, as disclosed in the volume entitled, 'Streams Examination,' prepared by the Sanitary District of Chicago, and of the physical conditions with reference to slope, of there being slack water pools formed in the river at different points, I should not anticipate a greater longevity of the typhoid organisms in the waters of the Illinois River than I have found in the waters of the Schuylkill and Delaware Rivers." (Hill, Vol. 8, 7515-18.)

Dr. Ravold offered in evidence certain experiments made by him upon the longevity of the typhoid fever germ in the waters of the Illinois and Michigan Canal, the Chicago River and the Drainage Canal. In his testimony we find, on page 475, that the typhoid fever germ in the window, Illinois

and Michigan Canal, Lockport, July 5th, the number of days that the bacillus lived was five. Drainage Canal, Western Avenue, Chicago, Illinois, June 13th, longevity, five days; July 15th, seven days. Drainage Canal, Lockport, June 13th, four days; July 5th, eight days. Illinois River above Peoria, June 13th, five days; July 5th, ten days. Illinois River, Pekin, July 11th, eight days; June 13th, four days; July 5th, ten days. Chicago River, Adams street, June 13th, four days. These experiments were in unsterilized water. In natural water, Illinois and Michigan Canal, Lockport, average number of days alive, five, in the window. Drainage Canal, Western Avenue, in the window, six days. Drainage Canal, Lockport, in the window, four and three-quarter days. Illinois River, above Peoria, average number of days alive in the window, seven and two-thirds days. Illinois River water, Pekin, in the window, seven days. Chicago River, Adams street, in the window, four days. (475-6-7.)

It will be observed that the experiments conducted by Dr. Ravold in the natural waters of the Chicago River, the Illinois and Michigan Canal and the Drainage Canal, in glass bottles, were under conditions as hereinbefore referred to, more favorable to typhoid longevity than in natural conditions, indicate only a comparatively greater duration of life than was found in the experiments conducted by Professors Jordan, Zeit and Russell.

Taking into consideration all the experimental data offered in evidence in this case, and as hereinabove referred to and set out in detail, where conditions obtain such as exist in the Chicago River, the Drainage Canal and the Illinois River, the life of the typhoid germ under those conditions is limited to a period of from three to six days.

Bacterial Purification of the Mississippi River as Shown at New Orleans—Weston.

One of the most remarkable samples of the self-purification of a stream is afforded in the case of the Mississippi River, as demonstrated by its condition at New Orleans. New Orleans

is 132 miles below Baton Rouge, 265 miles below Natchez, 366 miles below Vicksburg, 735 miles below Memphis, 960 miles below Cairo, 1,159 miles below St. Louis, 1,165 miles from the mouth of the Missouri River, 1,305 miles below Louisville, 1,415 miles below Cincinnati, 1,823 miles below St. Paul, 1,875 miles below Pittsburg.

The population of the watershed of the Mississippi in towns of 4,000 or more, including Chicago, was about 9,000,000 people in the year 1900. The sewage of this urban population reaches the total of 1,516,250,000 gallons per day. This is equivalent to a flow of 2,310 cubic feet a second at New Orleans.

In view of the enormous pollution entering the Mississippi River and its tributaries, making of this stream the central sewer for the North American continent, it is a notable circumstance that this stream has become entirely free from impurities at New Orleans.

The test for bacillus coli communis, the most delicate test that can be applied for pollution to any water, reveals the absence of this organism in the Mississippi River water at New Orleans, even when large amounts, ranging up to 300 c. c. were examined. There is not the slightest evidence that any unpurified sewage exists in the water of New Orleans, apart from that small amount which may occasionally have been washed from the banks of the stream outside of the levees, and in the immediate vicinity of the water purification station during the time the tests were made.

These facts are set forth lucidly and forcibly in the testimony of Mr. Robert Spurr Weston, who had charge of the chemical and bacteriological analyses of the water purification station at New Orleans in 1900 and 1901 under the supervision of an advisory board of six engineers, one of whom was Mr. Geo. W. Fuller, of New York, a witness for complainant in this case. The conclusive and uncontradicted testimony of Mr. Weston is sufficient in itself to demonstrate the reality of the process of self-purification of streams. (6870, 6890.)

The response of Mr. Fuller in reply to questions regarding

the self-purification of streams are, to say the least, quite peculiar. His answers are as follows:

"Q. You don't believe that there is any length of time or any conceivable distance for a stream of sewage to travel and in which time it will absolutely purify itself of infection?

"A. Taking that as an absolute proposition, I think it is very doubtful.

"Q. Do you believe that if the sewage of Chicago was poured into the Mississippi at St. Paul it would purify itself by the time it got to St. Louis?

"A. It would to a large degree, but I don't think it would be absolutely purified.

"Q. If poured into the Mississippi River at St. Paul, would it be dangerous to the people taking water at St. Louis at the intake?

"A. It would, in the sense that the liability of trouble would always exist, to my thought.

"Q. So that there is absolutely no such thing as the purification of a stream of running water into which infection is poured from sewage?

"A. Absolutely speaking, I think that is a very doubtful proposition." (2629.)

In connection with this, also may be cited the conception of Mr. Williams, as follows:

"Q. Can you conceive of any distance in a running stream in which typhoid fever bacilli might not live in the waters of that stream?

"A. The life of the typhoid bacilli in streams is rather a question of time and distance, and as a general proposition I would say that it is my present opinion that there is no stream of water on the surface of the earth, flowing in natural channels, that is long enough to warrant the absolute assurance that a typhoid germ might not live from one end of it to the other.

"Q. So if there were typhoid germs cast into the waters of the Mississippi River at St. Paul, and no other possible source of the infection of those waters, do you believe that those

typhoid germs might arrive at New Orleans and infect the water supply of the City of New Orleans?

"A. I think it is possible to a certain degree; that is, I think it is possible that some of them might arrive. I do not want to be understood as saying they would all arrive.

"Q. Are not all of such suppositions very vast extensions of any kind of knowledge upon that subject?

"A. I think not.

"Q. Do you know, in your experience or learning, of any instance in which even by the process of reasoning of scientists in water supply, or bacteriology, or chemistry, or of sanitary engineering, where they have determined to their own satisfaction that the typhoid bacillus has lived in running streams for a distance of over 150 miles?

"A. Yes, sir.

"Q. What instance?

"A. The instance of the pollution of the St. Louis supply by the drainage of the City of Chicago." (2548, 2549.)

In contrast to Mr. Fuller's testimony on the witness stand, as above quoted, may be set a citation from a report published by the Sewerage and Water Board of New Orleans, Louisiana, in 1903, and quoted in Professor Jordan's testimony at pages 6003, 6004. The work here referred to was largely carried out under the supervision of Mr. Fuller. The quotation from the report is given in Professor Jordan's testimony as follows:

"Bacillus Coli Communis.

"In waters which contain unpurified sewage, the test for this intestinal organism is of the utmost importance. In the Mississippi River at New Orleans, however, there is evidently so much self-purification effected by natural agencies, such as dilution, sedimentation, etc., that this normal intestinal bacillus was one of the least common of the forms isolated. In about 100 tests with volume of water, varying from 1 to 300 cubic centimeters, its presence was demonstrated only three times, although the larger samples of water were concentrated in a

centrifuge before being seeded into the media contained in fermentation tubes.

"The remarkable fact that bacillus coli communis was discovered only rarely in the water of the Mississippi River at this point, even when the large amounts of water were tested, illustrates the condition that is likely to prevail in a river water of this character when protected from the entrance of polluting matters during a considerable part of its course. I quote further from page 49 of this New Orleans report:

"'From what goes before, it will be seen that the Mississippi River at New Orleans, as evidenced by the data obtained during this investigation, is unusually pure from a sanitary standpoint. For instance, it is believed that if 100 cubic centimeter samples of water were taken from the Merrimac at Lawrence, the Hudson below the Mohawk, the Schuylkill, the Potomac, the Ohio at Cincinnati, they would show the presence of bacillus coli communis as a rule. Such is not the case with the Mississippi River water at New Orleans, because, as stated above, the opportunities for natural purification are so great during the last few hundred miles of its flow, and the amount of additional pollution received is so small in comparison to the discharge of the river, that the bacteria which one is accustomed to consider to be the normal inhabitants of surface water effectually crowd out those abnormal bacteria which are carried into the river with the drainage from populated and cultivated areas. It must also be remembered that the banks of the Mississippi above New Orleans are protected by levees. These levees also in turn protect the river from contamination, except where sewers exist. Since it is usually more convenient for the towns immediately above New Orleans to carry their drainage away from the river, almost no local pollution exists.'

"It is, in my opinion, certainly a striking and highly remarkable circumstance that the Mississippi River at New Orleans, after receiving countless millions of colon bacilli, contributed by the cities of the Ohio, Illinois, Mississippi and Mis-

souri Valleys, together with those on the many tributary streams, and bearing in mind the facts already instanced as to the relatively high longevity of the colon bacillus, should show itself so nearly free from organisms of this class.

"This condition furnishes a singular confirmation of the views that have been expressed regarding the sanitary significance of this organism when found in water supplies." (6003, 6004.)

Now it is evident that the question of self-purification is not one to be settled by such jaunty statements as those contained in the testimony of Mr. Fuller and Mr. Whipple, but it is rather such thorough and laborious investigations as those embodied in the New Orleans report just instanced, that are competent to determine this question. The condition of the Mississippi River at New Orleans unquestionably supplies one of the most striking samples of genuine self-purification of streams that has ever been made a matter of scientific record.

In connection with the demonstration of self-purification in the water of the Mississippi River, as evidenced at New Orleans, reference may be made to the statement by the Rivers Pollution Commission of Great Britain, referred to several times in this record. (6172, 6176, 7959, 7960.)

Professor Sedgwick, in his testimony, made from memory a quotation from this report of the Rivers Pollution Commission as follows:

"This epidemic (Washington) seems to confirm in a very remarkable way that statement of the Rivers Pollution Commission of Great Britain, to which I have referred in my previous testimony, where they said that there was no river in the world that was long enough to purify itself of any sewage introduced into it, even at its source."

The evidence of Professor Jordan shows that the statement in question contained two errors of some importance as bearing upon this case: First, that the statement did not refer to "any river in the world", but to any river in the "United Kingdom"; second, that instead of the expression "purify itself

of any sewage", the real statement referred to the oxidation of sewage. As shown by Professor Jordan in his testimony (6174), there is, from the modern view, a wide difference between stating that the purification of a stream is effected within a certain distance, and that the destruction of sewage by oxidation is accomplished within a certain distance.

The report in question was published in 1874, before the rise of the science of bacteriology, when practically nothing was known regarding the elements in sewage that imparted to it its dangerous character.

In rebuttal, Professor Sedgwick stated that the quotation to which he referred is that "there is no river in the United Kingdom long enough to secure the oxidation and destruction of any sewage which may be discharged into it, even at its source", rather than the very similar quotation introduced by Professor Jordan; "that it will be safe to infer from the above results there is no river in the United Kingdom long enough to effect the destruction of sewage by oxidation."

It will be noted that the reply of complainant's witness misses entirely the point raised by Professor Jordan, namely, that the oxidation and destruction of sewage in the sense in which these terms were necessarily used in 1874 is something very different from the purification of sewage as it is at present conceived. It is erroneous and misleading to say that the oxidation of certain chemical constituents of sewage is the same thing as the purification of sewage. This was the main reason why exception was taken by defendants to Professor Sedgwick's statement from memory, as is shown in Professor Jordan's explanation. (6174.)

Attention must, however, be directed also to the looseness of statement which would allow the transmutation of "no river in the United Kingdom long enough" to "no river in the world that was long enough". (2765.)

The application of the statement of the English Commission which had reference purely to chemical changes in the water, to an epidemic of typhoid fever, as done by

Professor Sedgwick (2765), is entirely unwarranted by any considerations of logic or plain speaking. In view of our modern conceptions of the sources of water borne disease, and especially in view of the definite observations upon the real self-purification of the Mississippi River, as shown in conditions at New Orleans, these statements of Professor Sedgwick, Mr. Fuller and Mr. Williams, which are mere matters of opinion, are shown to be gratuitous and unfounded.

Pollution and Its Effect Upon the Longevity of Typhoid Germs—Sedgwick.

The most remarkable statement made in the testimony of this case, unsupported, uncorroborated and at variance with the opinions of all scientific investigators who have testified in this case, was that made by Professor Sedgwick when he stated:

"*The mere presence of pollution—I mean by that uninfected sewage; that is, supposing Chicago had reduced her typhoid rate, she would still pour her sewage down the valley, and that sewage, by merely favoring the longevity or growth of germs which got in from Peoria or anywhere else, would be an added menace to cities with water supplies, even if she did not send typhoid fever germs down; sending the filth alone down is serious.*" (2223.)

And again he states:

"The pouring down of an unusual amount of organic matters from the stock yards, or from some other place, might so enrich the water as to sustain the life of the germs, perhaps even leading to a greater duration of life than that you have stated." (2315.)

If it were not for the statements that pollution added to the longevity of the typhoid germ, and special emphasis placed upon it by Professor Sedgwick, who has taken such an active part in this case as one of complainant's chief witnesses, the defendants would not feel called upon to offer testimony upon a proposition at such variance with the experience of scientific men to-day.

The evidence in this case, both that given by complainant as well as that given by the defendants, fails utterly to establish and sustain the proposition of Professor Sedgwick above enunciated. Dr. Ravold stated:

"We find that when we take water, for instance, from the Drainage Canal, that it contains on an average of 300,000 or 400,000 bacilli to the cubic centimeter. We sow typhoid bacilli in this water and for the first two, three or four days the water bacteria, not the typhoid bacilli, increase enormously and use up the nutritive material in the flask for food. The results of this destructive action on the organic matter, both solid and liquid, in the water results in the production of poison. True, toxin and enzymes and these products seem to act not only deleteriously upon one another, but upon the pathogenic microorganism in the water also, so that we see in the laboratory experiments that the bacteria in the living waters die much quicker than they do in sterile distilled waters, or than in river waters sterilized." (791.)

Mr. George W. Fuller, one of the complainant's witnesses, was asked this question:

"Q. If a considerable portion of that sewage was infected and once got into the Desplaines River, the typhoid infection would lie there in the sediment for a considerable portion of time, wouldn't it?

"A. It might, but I don't think that infection would get into the Desplaines River to any large degree, because of this septic action, which, owing to the very nature of the process, means a very tremendous growth of certain kinds of bacteria, the action of which is known to have a destructive influence upon the germ of typhoid fever." (2645.)

We know from the evidence in this case that *septic action* only takes place when there is a great amount of pollution present; and hence, with a large amount of pollution supplying food for the saprophytic bacteria, these saprophytes create a product which is destructive of the typhoid germ.

Professor E. O. Jordan testified on this question as follows:

"Q. Will the germ of typhoid live as long in polluted water as in pure or sterilized water?

"A. No, sir; I think it will live longer in pure water than in polluted water, and it is well known from the experiments of many observers that it lives longer in sterilized water than in unsterilized.

"Q. How do you account for this?

"A. I attribute the relatively speedy death of the typhoid bacillus in polluted waters as compared with pure and in unsterilized waters as compared with sterilized to the action of the various saprophytic microbes which inhabit these waters. Where the typhoid bacilli are removed from competition with these saprophytic forms, as in the case where they are introduced into sterilized waters, they live longer than under the conditions where they may be injuriously affected by the products of other microbes. In the case of the polluted waters, the greater concentration of organic matter may favor a more intense action of the products of the saprophytic microbe present in these waters. In other words, these products in the polluted water are in more concentrated form than is the case in the pure water, and so bring about the death of the typhoid bacillus sooner. It is, therefore, to the action of the saprophytic microbes that I attribute the dying off of the typhoid bacillus in polluted waters and in unsterilized waters.

"Q. From your knowledge of the character and quality of the waters of the Drainage Canal, the Desplaines River and the Illinois River, what is your opinion as a bacteriologist as to the longevity of the typhoid bacillus in these waters?

"A. From what I know of the chemical composition and bacterial content of the waters of the Illinois River at various points along its source, it is my opinion that the life of the typhoid bacillus introduced into the Illinois River at the upper end of the Drainage Canal would not be more than three or four days.

"Q. What reasons have you for the opinion that the life of a typhoid bacillus in the waters of the Drainage Canal, the

Desplaines and the Illinois Rivers is shorter as compared with the laboratory experiments?

"A. In the water of the Desplaines and the Illinois Rivers the typhoid bacillus is subjected to the unrestricted action of the products of the various saprophytic microbes that inhabit these waters. The large amount of organic matter in the upper stretches of the river favors the concentration and the consequent intensity of action of these saprophytic products. As compared with the laboratory conditions again, the typhoid bacillus can hardly be favored in these waters by the presence of any such substances as go into solution from the glass bottles used in laboratory tests. These two reasons, therefore, the absence of the favoring laboratory conditions and the free and vigorous action of the products of growth of saprophytic microbes, lead me to adopt the opinion that I have just expressed. (6160, 6161.)

"Professor Sedgwick, on page 3495, in answer to a question, among other things, answered: 'The mere presence of pollution, I mean by that uninfected sewage, that is, supposing Chicago reduced her typhoid rate and could still put her sewage down there, that sewage, as affecting the longevity or growth of germs which go in from Peoria or anywhere else, would be an added menace to cities with water supply, even if she did not send typhoid fever germs down; sending the filth alone down is serious.' I will ask you what is your opinion, based upon your experience as a bacteriologist and sanitarian, that the sewage from Chicago favors the longevity or growth of germs from Peoria or anywhere else, emptying their sewage into the Illinois River?

"A. On the contrary, it is my opinion that the introduction of sewage or organic matter of a similar character into the river water is distinctly detrimental to continued longevity or growth on the part of the typhoid fever bacillus. In my judgment, the experiments carried out upon the life of the typhoid fever bacillus in the waters of the Drainage Canal show that the presence of a considerable amount of organic

matter or sewage in the water favors the speedy dying out of typhoid fever bacilli, rather than their continued vitality. As I have already pointed out, this is what might be anticipated in view of the greater concentration of the toxic products of saprophytic microbes in waters highly charged with organic matter than in purer waters.

"This being the case, it would follow that typhoid fever germs passing into the river from Peoria would not be favored in any respect by the fact that Chicago sewage had entered the Illinois Valley 150 miles above. On the other hand, they might be actually injured by the products originating from the decomposition of such sewage which were carried down even as far as Peoria.

"Q. Does the presence of sewage in water add to the longevity or growth of pathogenic bacteria?

"A. I have already stated that I considered the presence of sewage in water under natural conditions does not add to the longevity or growth of pathogenic germs, but favors their speedy dying out." (6324, 6325.)

Professor Russell, in answering the same question put to Professor Jordan, hereinabove quoted, stated:

"It is my opinion that the deposition of sewage of Chicago into the Drainage Canal does not increase the longevity of the typhoid organism deposited therein, but, on the contrary, is a potent factor toward the more rapid destruction of the vitality of the typhoid organism than would be the case if such sewage were not so deposited. * * *

"When sewage is added to the water in an unsterilized condition, such as would exist when normally deposited in drainage canals, the addition of such sewage does not increase the longevity of the typhoid organism, but, on the other hand, is a distinct factor in the early death of the typhoid organism." (6573.)

And Professor E. G. Smith, in answer to the same question, stated:

"From the evidence already given in this case, and par-

ticularly the positive results of the experiment by Doctors Zeit, Jordan and Russell, in which they have demonstrated that the typhoid germs from the City of Chicago can live but a short period in this sewage laden water, such period covering, according to those observations, perhaps three or four days, it is my opinion that the sewage of Chicago does not favor the longevity or growth of germs from Peoria or any other city also emptying its sewage into the river, but, on the contrary, the same agencies which have operated in this river, which have tended to diminish the viability of typhoid fever, would still be operative upon typhoid fever germs coming from points below.

"From all knowledge I have been able to gather by study upon this question and from the study of the experiments by Doctors Zeit, Jordan and Russell, it is my opinion that the presence of sewage in water tends to diminish the viability of the typhoid bacillus." (6825.)

The foregoing testimony, which is in accord with the experience of scientific investigators, shows that pollution does not add to the longevity of the typhoid organism; and the foregoing statement of Professor Sedgwick is but another instance wherein he makes assertions of fact which are not sustained or supported by scientific research. He is the only witness who has testified in this case among the eminent scientists who have appeared, that has advanced the proposition that pollution adds to the longevity of the typhoid germ.

IV.

THE WATER OF THE ILLINOIS RIVER AT GRAFTON, SINCE THE OPENING OF THE DRAINAGE CANAL, AS DISCLOSED BY CHEMICAL AND BACTERIAL SURVEYS COVERING A LONG PERIOD OF TIME, IS, IF ANYTHING, IN A BETTER SANITARY CONDITION SINCE THE OPENING OF THE DRAINAGE CANAL THAN IT WAS PRIOR THERETO.

Sanitary Condition of the Illinois River Prior to 1899.

The Illinois River affords better opportunities for sedimentation and chemical purification than most other rivers in this western country. On account of the sluggishness of its current and its overflowed meadows and lowlands, the opportunity for the deposition of matters in suspension obtains in this river to a wonderful degree.

Bearing in mind that, prior to 1900, a great volume of sewage entered the Illinois and Michigan Canal through the Bridgeport pumping works, which in turn empties into the Desplaines and Illinois Rivers through that canal, the conditions, as disclosed by the chemical results, show that the Illinois River purified itself of this sewage during its flow from Joliet, long before Peoria was reached.

Based upon the results of his examination of the river in 1886, which is set out in the printed record at page 4029, Professor Long states:

"These analyses show beyond any question a very marked destruction of organic matter in the flow between Bridgeport and Peoria, showing the effect of what is called bacterial oxidation in an extremely marked degree, the water at Peoria in that particular season being practically potable and actually used by a large number of people. I was at Peoria during the season and observed that fact myself. This effect is partly, of course, due to the oxidation and also to the dilution from tributaries, but the largest part of the effect is unquestionably due to actual destruction by bacterial oxidation." (4029.)

Based upon his analyses in the winter of 1886 and 1887, the results of which are set out on pages 4029-4031 of the printed record, he states that he draws "the conclusion that in the winter of 1886 and 1887, as in the summer of 1886, there is a very considerable destruction of organic matter in this stretch between Bridgeport and Peoria, but the destruction or oxidation is much less marked and characteristic than in the summer, as is always the case in these observations".

In the chemical survey made by Professor Long, from Bridgeport to Alton, on the Mississippi River in 1888, the analytical results appearing in the printed record (4033 to 4044), he states:

"These results show a purification of the river between the source of the water at Bridgeport and the outlet of the Illinois River at Grafton. The purification, measured by the destruction of organic matter, showed a very great or a very marked diminution of the organic matter. This diminution of the organic matter is due to two principal factors, the dilution of the stream by the waters from various tributaries, and to the destruction of the organic matters by the oxidation, using that term in a general sense, or broad sense. The disappearance of organic matter is very much more marked than is the dilution, as is indicated by the change in chlorines, the condition being finally reached in which the organic matters are not larger or greater in amount than in the tributary streams." (4040.)

"I made, at the same time that these analyses referred to were made, examination of the waters of the Du Page River, the Kankakee River, the Fox River, the Big Vermilion River, the Little Vermilion River, the Sangamon River." (4041.)

These chemical analyses appear on pages 4043 to 4071 of the record, and in this connection Professor Long states on page 4072:

"The consideration of these tables which have been referred to and given by me, and the comparison of the results of the analyses of the Illinois River at its mouth, with the re-

sults of the analyses of the tributaries of the Illinois River, indicate that a condition of organic purification of the Illinois at its mouth has been reached, which is comparable with or similar to that found in the tributaries mentioned. As indicated by the various tests which have been described, the organic matters in the Illinois River have been reduced to a point where they are not any larger in general than the organic matters found in the several tributaries. They have been reduced to a point beyond which the destruction of organic matter in the river by natural means cannot practically be exceeded or surpassed. Apparently the limit of oxidation of the organic matters has been reached. The practical limit of oxidation has been reached in the Illinois River, judging from these comparisons. We have here a condition in which the organic matters have been broken down and destroyed largely, and the residues that are left not destroyed are of a stable type, very resistent to all oxidizing influences, a condition characteristic of organic matter of vegetable rather than of animal origin, from which I conclude that in general these organic matters must be attributed to the leachings of the soil; that is, to products of vegetable origin rather than to products of animal origin.

"This condition obtains in all rivers to some extent, and in the Illinois River at its mouth and its tributaries.

"The organic matter in the Illinois River at points far above its mouth is, in general, larger than the organic matter in most of its tributaries, but by the time the mouth of the river has been reached the organic matter has become so far reduced that it compares in general very closely with that found in the tributaries, and does not exceed that in the tributaries in general." (4073.)

"The water of the Illinois River at Grafton in this season, in the summer of 1888, has reached a degree of organic purity fully equal to the mean condition of the waters in the tributaries mentioned, the Du Page, the Kankakee, the Fox, the Big and Little Vermilion, and the Sangamon.

"In drawing this conclusion, I have taken into consideration essentially these three factors: The amount of free ammonia, the amount of albuminoid ammonia and the figure representing the oxygen consumption. I have also considered the condition of oxidation as shown by the amount of nitrates—nitrogen as nitrates. There are four elements in reality going to make up this conclusion, and by comparison of these four elements it has been shown that the Illinois River has reached a condition of organic purity comparable with the tributaries." (4074.)

"In the breaking down of the vegetable organic matters in the water and in the leaching out of the organic matters from soils into water, products are present which are comparatively stable, which tend to persist and resist the destructive influences of bacterial action in general more markedly than do those of animal origin. The characteristic nitrogenous substances excreted by the animal—urea, uric acid, hippuric acid—undergo oxidation very much more readily than do the corresponding substances of vegetable origin. The more complex products of animal origin break down finally into substances of comparatively stable type, which do not use up very much oxygen in the oxidation process. The substances of vegetable origin use up more oxygen than do those of animal origin which have been subjected to bacterial influences. While fresh substances of animal origin consume large amounts of oxygen, the bodies of animal origin which have been in water a long time have reached a condition of disintegration, forming products of comparatively stable type. Among the substances of animal origin the nitrogenous derivatives are the most characteristic. Among the substances of vegetable origin the carbo-hydrates, on the other hand, are the most characteristic and these bodies are pre-eminently those which are characterized by the oxygen consuming power. * * * These bodies show marked oxygen consuming powers, so that these facts I have taken into consideration in the statement which I made a while back, that the oxygen consuming

power in the lower Illinois River corresponds practically to what we can expect from a water fed from the tributaries of the Illinois River, and can be fully accounted for by considering the tributaries and not the nitrogenous waste coming from the original sewage starting at Chicago." (4076.)

"I have seen the whole of the Illinois River by daylight on several occasions. I have started at Grafton and come up the Illinois River by daylight as far as La Salle, and have continued the trip several times by rail along the banks of the river. I have gone down the river also again from Chicago to Lockport, and along the banks of the river to La Salle, and from La Salle or a point immediately below, known as Peru, to the mouth of the river. I have been on the Desplaines River a great many times hunting and fishing, near the mouth and further up. I have been on the Du Page River, and have been up and down the Kankakee River from its mouth practically to its source in Northern Indiana. I have been on the Sangamon River at several points and have paid attention to the appearance of the water. I have been also on the Vermilion River up to Streator, which is some distance from its mouth—the Big Vermilion River. I have acquaintance with the Spoon River and the Little Vermillion River only by observation of points where they have entered the Illinois." (4077.)

"I have personal knowledge of the source of such contamination entering the Illinois River and its tributaries." (4077.)

In the examination made of the Illinois River, referred to by Professor Long in 1888 and 1889, where samples were taken from Bridgeport, Lockport, Joliet, Morris, La Salle, Henry, Peoria, Pekin, Havana, Beardstown, Grafton and Alton, he draws the following conclusions (4079):

"This table, giving the summary of the analyses made during the winter of 1888 and 1889, shows a considerable reduction of organic contamination of the water between Bridgeport and Grafton, but a very much less marked degree of reduction than was observed in the summer of 1888. This difference is particularly noticeable in the factor for the oxygen consumption.

and for the albuminoid ammonia, and it is also shown by the factor expressing the amount of the free or saline ammonia present. One of the most important points in this table is found in the figures showing the amount of free ammonia, albuminoid ammonia and the extent of oxygen consumption at Pekin during the winter. While in the summer work the amounts of organic matter in the river at Pekin, as disclosed by the analyses, does not appear to be excessive, at any rate no very great increase is detected there, during the winter of 1888-1889 these factors show, especially as regards the undecomposed nitrogenous substances indicated by the albuminoid ammonia, a very large residuum. The condition indicated by the figures for oxygen consumption is also one of increased organic contamination. The explanation of this is not difficult and should be given here.

"During the summer seasons in the stretch between Peoria and Pekin, which is a nearly level stretch of eight or ten miles in extent, an enormous decomposition of organic matter occurs, as is observable in passing through the stream. This decomposition is a bacterial or fermentive decomposition, as disclosed by the rapid evolution of gases in this part of the stream, so that, roughly, this stretch may be compared to a great septic tank in which hundreds of tons of organic matter are undergoing decomposition all the time. The rate of decomposition of organic matter varies, as is well known, by temperature. In the winter season, therefore, we have this rate very much slower, so that at Pekin, below the distilleries and cattle sheds of Peoria, the enormous pollution, as indicated by the residual albuminoid ammonia factor and the factor for oxygen consumption, indicates fresh and recent additions.

"The consideration of these figures shows, beyond any question whatever, that the addition of filth at Peoria is a very important factor in accounting for the organic matter in the river below." (4080.)

"The comparison of the results obtained in the Illinois River in 1886 with those obtained two years later, 1888, 1889,

indicate increased pollution of the Illinois River at Peoria. From personal observation of the Illinois River at Peoria in 1886, I know that the water was potable, and formed a large part of the water supply of the City of Peoria. From personal observation I know that later this water supply was abandoned because of the increasing pollution of the river, which was shown also by the analyses." (4099.)

From the foregoing testimony offered in evidence in regard to the sanitary condition of the Illinois River for the period wherein it was under the investigation of Professor Long, the evidence is conclusive and not contradicted that the Illinois River purified itself of all sewage which was emptied into it by the Illinois and Michigan Canal before the City of Peoria was reached; and after the enormous amount of sewage from the cattle sheds and distilleries at the City of Peoria was emptied into the river, before Grafton was reached, the Illinois River had again purified itself of this sewage and had assumed the normal sanitary conditions such as existed in the tributaries of the stream, or at a point above Peoria.

These facts, set forth in the tables of analyses which appear in the testimony of Professor Long, demonstrate that the Illinois River is a stream which purifies itself of pollution entering into it at its source or contributed to it by the cities lying tributary to its banks.

A comparison of the chemical and bacterial analyses of the Illinois River for the year 1899 *with the year* 1900 *shows conclusively that the Illinois River purifies itself of Chicago sewage before Averyville is reached.*

On January 17, 1900, the bear-trap dam at Lockport was lowered and water which had been let into the Drainage Canal on the 2d day of January, 1900, was permitted to flow westward into the Desplaines and Illinois Rivers. The effect of this sewage from Chicago, diluted with the pure water of Lake Michigan, is best ascertained by a comparison of conditions which obtained in the Illinois River during the previous year with conditions as they existed in that river during the following year.

In view of the testimony offered in this case by complainant's witnesses, the wisdom of having made a chemical and bacterial survey of the waters of the Illinois River, the Mississippi and Missouri Rivers, for the year 1899, is plainly manifest.

The complainant offered in evidence in this case the analyses which were conducted by the City Chemist of St. Louis prior to the opening of the drainage canal, which in number of samples was so small as to be of very little value and insufficient to justify the conclusion which the City Chemist drew from them.

During the period of 1899, from April to the last of December, the Sanitary District conducted an extensive chemical and bacterial survey of the waters in question, as heretofore explained, and as submitted to the court in the evidence of Dr. Gehrmann and Mr. Bisbee, who had charge of the municipal laboratory of the City of Chicago; also the chemical and bacterial data which have been offered in evidence and submitted to the court by Professors Palmer and Burrill, who conducted the investigation at the University of Illinois laboratory; and also the analytical data and tables, both chemical and bacterial, which were obtained in the laboratory of the University of Chicago by Professor E. O. Jordan.

Independent of this triple investigation made by the Sanitary District, Professor J. H. Long and Professor Robert F. Zeit, in behalf of the State of Illinois, carried on a chemical and bacterial survey of these waters in 1899; and the chemical and bacterial data have been presented to the court in the evidence of each of these respective witnesses. The conclusions of these analysts, both chemical and bacterial, drawn from the chemical and bacterial data heretofore submitted by them in evidence, show the condition from a chemical and bacterial standpoint of the sanitary conditions of the waters of the Desplaines, Illinois, Mississippi and Missouri Rivers in 1899 and in 1900.

Prior to the introduction of the testimony of these analysts

the tables of analytical data were published in book form by the Sanitary District under the title of "Streams Examination", by which name this compilation is known and spoken of throughout the record in this case by counsel representing either side of this controversy.

In addition to the opinions of the chemists and bacteriologists, who made the determinations that appear in the evidence and were published in "Streams Examination", the defendants in this case placed upon the stand the following witnesses: Professor H. L. Russell, of the University of Wisconsin; John W. Hill, in charge of the filtration plant at Philadelphia; Professor Leonard P. Kinnicutt, of the Worcester Polytechnic Institute at Worcester, Massachusetts; Professor W. P. Mason of Troy Polytechnic, and Professor E. G. Smith, of Beloit College, who, after a careful study of the analytical data as the same appears in "Streams Examination", expressed their opinion in regard to the sanitary condition of the Illinois River before and since January 17, 1900.

The average flow in the Illinois and Michigan Canal prior to 1900 was from 35,000 to 36,000 cubic feet per minute. (5101.)

Professor Jordan, after having introduced the tables of his analytical data for the period of 1899, beginning with Bridgeport to the City of St. Louis, testified as follows:

"Table No. 81 (5818) shows the results of analytical determinations upon the water of the Illinois and Michigan Canal at Bridgeport, * * * and shows that the water in the Illinois and Michigan Canal was on these days simply sewage, varying in degrees of concentration and staleness."

"Table No. 82 (5819) shows the analyses made from the water obtained from the Illinois and Michigan Canal at Lockport, a distance of some twenty-nine miles from Bridgeport. The significant constituents of the water show that but little change has taken place, except that it is further advanced in decomposition."

"Table No. 83 (5822) contained the detailed analyses of samples of water from the Desplaines River at Lockport, Illi-

nois, obtained on different days from May 5, to December 26, 1899. The amount of the several significant constituents of this water indicates a water more or less polluted. The Desplaines River in fact receives sewage from several of the suburbs of Chicago. The points selected from which samples were taken was above the mouth of the present Drainage Canal. The Desplaines River received sewage from the suburbs of Chicago, Riverside and other places that directly empty into it."

"Table No. 84 (5825). Samples for this table were obtained from the Desplaines River north of Jackson Street at Joliet, Illinois. From the chemical and bacterial constituents of this water it is evident that the mingling of the waters of the Desplaines with the waters of the Illinois and Michigan Canal have resulted in little alteration of the composition of the canal water. The Desplaines River at this point must be regarded as a stream charged with sewage."

"Table No. 87 (5828) contains analyses of samples of water taken from the Illinois River at Morris, Illinois, between May 29 and December 26, 1899. About nine miles above Morris the waters of the Kankakee mingle with the waters of the Desplaines River, forming by their junction the Illinois River proper. The water of the Illinois River at Morris, therefore, shows the influence of dilution of the highly polluted Desplaines River with the purer waters of the Kankakee, although the commingling is not complete at this point. Some change in the composition of the water appears also to have taken place during its passage from Bridgeport to Morris."

"Table No. 88 (5833) includes analyses of water from the Fox River, near its mouth at Ottawa, Illinois, for this period. Sewage from several towns enters the Fox River, the principal towns being Elgin, with a population of about 22,000, and Aurora, with a population of about 26,000. Aurora is about forty miles above the mouth of the Fox River, and Elgin is about fifty-five miles. The composition of the water is what might be expected from its origin. It is a water receiving some sewage."

"Table No. 89 (5835) contains the results of analyses of water from the Illinois River at Ottawa, Illinois, for this period. In the flow from Morris to Ottawa a very considerable change takes place in the composition of the water. This is partly due to more thorough mixing, but in a large part due to changes in the constituents of the water. The albuminoid ammonia and free ammonia, the oxygen consumed, the number of bacteria, are all lower than at Morris, indicating that a really considerable purification of the water has taken place during its passage from Morris to Ottawa."

"Table No. 90 (5837) includes the analyses of water from the tributaries of the Illinois, the Big Vermilion River entering the Illinois above La Salle; the sewage of Streator and Pontiac enter the Big Vermillion. The determinations for chlorine and residue on evaporation were influenced by the operation of a cement factory a short distance above the point of collection. This affords an explanation for the large amount of residue on evaporation and for the high chlorines in September, October and November of this year."

"Table No. 91 (5839) contains the analyses of the samples of water from the Illinois and Michigan Canal at La Salle for this period. The large amount of free ammonia and albuminoid ammonia and the large number of bacteria show considerable pollution is present at this point."

"Table No. 92 (5841) contains the analyses of samples from the Illinois River at La Salle. The various determinations show that considerable purification has taken place in the Illinois River during the flow from Ottawa to this point, a distance of twenty-two miles."

"Table No. 93 (5843) contains analyses of water from the Illinois River at Henry, Illinois. At La Salle the sewage and drainage of La Salle and Peru, with a combined population of about 17,000, enters the Illinois and Michigan Canal, which discharges into the river and into the river itself. Little additional impurity enters the river between La Salle and Henry, and little dilution enters."

"Table No. 94 (5845) contains analyses of samples of water from the Illinois River at Averyville, Illinois, the samples being taken on various days between May 30 and December 26, 1899. Between Henry and Averyville there is practically no addition of impurity and little dilution, so that the changes occurring in the flow of thirty-six miles are due to oxidation and other processes. The point where the samples were taken is at the place known as The Narrows, near the Peoria waterworks, above the City of Peoria, and before any pollution from the city enters the river. The large amount of nitrogen in the form of nitrates at this point shows that a very considerable amount of oxidation of the organic matter has taken place. *The small number of bacteria shows that the stream which was originally laden with the bacteria of the Chicago sewage, derived from the Illinois and Michigan Canal, has practically freed itself from these bacteria in this flow of about* 160 *miles.*"

"Table No. 95 (5847) contains analyses of samples of water taken from the Illinois River a short distance below Peoria, near the place known as Wesley City. A large part of the sewage of Peoria, with a population of about 60,000, enters the Illinois River between Averyville and Wesley City. In addition to the house sewage, the discharges from extensive stock yards, the slop from distilleries and other refuse enter the river about this point of collection. The large number of bacteria in the water indicates the organic character of a large part of this pollution, and shows the extent as well as the nature of the defilement."

"Table No. 96 (5849) contains analyses of samples of water taken from the Illinois River at Pekin. The mixing of the Peoria sewage and refuse with the river water has become more nearly complete by the time this point is reached, and in addition the sewage of Pekin, a city with a population, I believe, of about 8,000, has entered the river, together with considerable distillery refuse. The sample was taken far enough below Pekin to get the effect of all this pollution, so far as practicable, to show the mixing of the pollution, although here, as

at Wesley City, the amount of pollution shown by the water in the middle of the stream was not the same at all times."

"Table No. 97 (5851) contains analyses of samples of water taken from the Illinois River at Havana. A considerable decrease of purification takes place betewen Pekin and Havana, as shown by the different determinations in this table."

"Table No. 98 (5853) contains analyses of samples of water taken from the Sangamon River at Chandlerville, Illinois. Chandlerville is about twenty miles above the mouth. A very considerable amount of sewage enters the Sangamon River and its tributaries from Springfield, with a population of about 35,000; from Bloomington, with a population of about 24,000, and from Decatur, with a population of about 20,000. This very considerable amount of pollution is not particularly manifest in any of the determinations in this particular table, but it comes out with considerable clearness in the determinations which were made for the relative abundance of colon bacilli, as will be shown in tables that will be presented later."

"Table No. 99 (5855) contains analyses of samples of water from the Illinois River at Beardstown. Between Havana and Beardstown the Sangamon River enters, but otherwise little additional impurity is added to the river."

"Table No. 100 (5857) contains analyses of samples of water taken from the Illinois River at Kampsville, Illinois. Between Beardstown and Kampsville only a very small amount of polluting material enters the Illinois River. In fact, from Beardstown to the mouth of the river at Grafton, the polluting matters entering the rivers are relatively insignificant. Some dilution, however, occurs from small tributary streams. *The small number of bacteria found on many occasions in the water of the Illinois River at Kampsville, together with the amount of nitrates in the water, shows that the river at this point has practically regained the condition that it possessed at Averyville, above Peoria.*"

"Table No. 101 (5859) contains the analyses for Graf-

ton. These samples were taken at a point in the Illinois River where no mixing with the Mississippi River water was possible. The condition of the Illinois River at this point compares very favorably, chemically and bacterially, with the waters of the Illinois River at Averyville and with the various tributary streams entering the Illinois."

"Table No. 102 (5861) contains the analyses of samples of water taken from the Mississippi at Grafton. The collections were made at a point in the Mississippi River where no mixing of the water with the Illinois River was possible. From a sanitary standpoint the water of the Mississippi River above Grafton does not differ materially, so far as can be determined, by chemical and bacterial examinations, from the waters of the Illinois River at its mouth."

"Tables Nos. 103-4-5-6 and 107 (5862-5866) contain results of analyses of samples of water taken from the Mississippi River above Alton, about twenty miles below the mouth of the Illinois River. The samples were taken at approximately equidistant points across the river, with a view to determining, so far as practicable, the extent of the mingling of the waters of the Illinois and Mississippi Rivers at this point. The degree of the commingling of the waters of the Illinois and Mississippi at this point is approximately shown by the chlorine determination. The higher chlorine on the east bank shows that a portion of the Illinois River water still hugs the Illinois shore, and that the water west of midstream to the right bank was largely if not altogether Mississippi River water."

"Table 112 (5869) contains the analyses of samples of water taken from the Missouri River at Fort Bellefontaine. Owing to the difficulties in making arrangements for the collection of samples, the analyses of water from this source were begun later than in the other case, so that the average of these determinations is not strictly comparable with the averages of other determinations, covering a different period."

"Tables 108-9-10-11 (5874) contain analyses of samples of water taken in cross-sections from the Mississippi River at

the Chain of Rocks, opposite the pumping station of the St. Louis waterworks. Between Alton and the Chain of Rocks the Missouri River enters the Mississippi River, some six miles above the point of collection. The Missouri River, like the Illinois, has a high chlorine content and contains, as a rule, more bacteria per cubic centimeter than the waters of either the Mississippi or Illinois."

"Table No. 118 (5882) contains the analyses of samples of water drawn from the tap in the City of St. Louis, Missouri. The diminished amounts of suspended matter and the smaller number of bacteria in the tap water bears witness to some of the changes effected in the passage of the Mississippi River water through the settling basins."

"The foregoing tables are the chemical analyses for the period prior to the opening of the Chicago Drainage Canal. The canal was not filled until the 1st of January, 1900, and the water did not pass out from the canal into the Illinois Valley until the 17th day of January, 1900."

Second Period of Analyses and the Tables Which Cover the Period From the 1st of January to the End of June, 1900.

By Professor Jordan.

"Table No. 119 (5884) contains the analyses of samples of water taken from Chicago Drainage Canal at Kedzie Avenue, nine samples of water being taken between April 30 and January, 1900. As compared with the character of the water of the Chicago River, pumped into the Illinois and Michigan Canal at Bridgeport during the period covered by the analytical work in 1899, these analyses indicate a water proportionately much less impure and much less heavily loaded with organic matter."

"Table No. 120 (5886) contains analyses of samples of water taken from the Illinois and Michigan Canal at Bridgeport, from January 2, to April 23, 1900. Some effect of the dilution of the contents of the Chicago River is shown by the various determinations in this table, the water of the Illinois and Michigan Canal being during this period less highly

charged with putrescible organic matter than was the case before the opening of the Drainage Canal, with the consequent influx of pure water from Lake Michigan. At the same time the proximity of the pumping station at Bridgeport to the south branch of the Chicago River, which is a practically dead end, allowed at times much organic matter and many bacteria to enter the canal."

"Table No. 121 (5888) contains analyses of water taken from the Illinois and Michigan Canal at Lockport from January 2 to June 25, 1900. The change in the flowing from Bridgeport to Lockport during this period is, as in the 1899 series, not a marked one."

"Table No. 126 (5898) contains analyses of samples of water taken from the Kankakee River at Wilmington from January 2 to June 23, 1900. One of the chief differences between the analyses of the Kankakee River for 1899 and 1900 appears in the number of bacteria per cubic centimeter, the number being higher through the winter and early spring months of 1899."

"Table No. 127 (5900) contains analyses of the samples of water taken from the Illinois River at Morris between January 5 and June 26, 1900. During the month of January the conditions were not dissimilar to those prevalent during 1899, but the analyses for subsequent dates show, in several ways, the effect of the dilution of the Chicago sewage in the Chicago Drainage Canal. The smaller amount of chlorine particularly is evidence of this increased dilution, and on several occasions, notably in the month of May, the number of bacteria in the Illinois River at this point was lower to a striking degree than at any time in the preceding period."

"Table No. 128 (5902) contains the analyses of the samples of water from the Fox River at Ottawa between January 4 and June 25, 1900. During the early part of this period the number of bacteria was much higher than in the period of 1899, and much higher for the latter part of April and for May and June, 1900. This is a phenomenon of common occurrence in

water in the Illinois River at Averyville for the same period. Both the effect of purification and dilution are shown in this table, especially during the latter part of the period, when the effect of the condition of early spring has disappeared."

"Table No. 135 (5916), contains analyses of samples of water in the Illinois River at Wesley City. The smaller number of bacteria during this period as compared with the 1899 period shows that the pollution entering the Illinois River at Peoria has been crowded in part towards the western bank and does not make its presence so evident in mid-stream as was the case during 1899."

"Table No. 136 (5918), contains analyses of the samples of water taken from the Illinois River at Pekin during this period. At Pekin the effect of the pollution in the mid-stream samples is more manifest than in the samples from Wesley City, owing possibly to a more thorough mixing at this point."

"Table No. 137 (5920), contains analyses of samples of water taken from the Illinois River at Havana for the same period. The purification in the river is shown by the number of nitrates and the number of bacteria as manifested here, as well as in the 1899 period."

"Table No. 138 (5922), contains analyses of samples of water from the Sangamon River at Chandlerville. The usual increase in the number of bacteria is manifest at this point as in the other tributaries of the Illinois, and in the Illinois River itself."

"Table No. 139 (5924), contains the analyses of the samples of Illinois River water at Beardstown for the same period. Taking into consideration the greater dilution of the water at this point, the analytical data are not materially different from those covering the 1899 period."

"Table No. 140 (5926), contains the analyses of the samples of water taken from the Illinois River at Kampsville for the same period. The usual spring rise in the number of bacteria, the amount of free ammonia and albuminoid ammonia and so on is manifest here as elsewhere, but during the latter part of the

river waters, and, so far as I am aware, no adequate explanation for this occurrence has been adduced."

"Table No. 129 (5903) contains analyses of samples of water from the Illinois River at Ottawa for the same period. The various determinations, chemical and bacterial, especially those showing the amount of albuminoid ammonia and free ammonia and nitrates and the number of bacteria per cubic centimeter, indicate that a considerable change in the direction of purification has taken place between Morris and Ottawa, as in 1899."

"Table No. 130 (5906) contains analyses of samples of water from the Big Vermilion at La Salle between January 2 and June 26, 1900. The number of bacteria during this period is, on the whole, higher than during the period for 1899. The amount of free ammonia during the first part of this period is much higher than in the latter part of the period."

"Table No. 131 (5908), contains analyses of the samples of water from the Illinois River at La Salle for the same period. During the months of January, February and March, the number of bacteria in the river is as in the other river waters that have been considered, much higher than during 1899. The amount of free ammonia is likewise much higher during the first part of this period than during the latter portion."

"Table No. 132 (5910) contains analyses of samples of water from the Illinois and Michigan Canal at La Salle for the same period."

"Table No. 133 (5912), contains analyses of samples of water from the Illinois River at Henry for the same period. Here again is shown the increase in the number of bacteria in the river water during the late winter and early spring. This has already been shown to be a common phenomenon in river waters and occurs in the tributaries of the Illinois as well as the Illinois itself. The diminished chlorine in the latter part of this period shows the effect of the dilution due to the opening of the Chicago Drainage Canal."

"Table No. 134 (5914), contains analyses of samples of

period the condition of the water both chemically and bacterially compares very favorably with that in the 1899 period. The number of bacteria averages less at Kampsville than at Averyville. The amount of free ammonia is, on the whole, lower. The albuminoid ammonia is very similar."

"Table No. 141 (5929), contains analyses of samples from the Illinois River at Grafton. A very considerable degree of purification is shown chemically and in the latter part of the period, bacterially, also, as compared with the collecting stations in the upper stretches of the river. The increased volume of water in the Illinois River especially in the months of March and April, is reflected in the lower chlorine contents during this period."

"Table No. 142 (5930), contains analyses of samples of water taken from the Mississippi River at Grafton. The amount of albuminoid ammonia in the water of the Mississippi during this period is, on the whole, somewhat higher than the amount of the Illinois River from samples taken on similar dates."

"Tables No. 143-4-5-6-7 (5931 to 5935) contain analyses of a series of five samples taken at approximately equi-distant points across the Mississippi above Alton, Illinois; the points of collection were the same as during the 1899 period. The analyses show that as in the 1899 period there is a lack of complete commingling of the waters of the Illinois and Mississippi Rivers at this point, the water derived from the Illinois River clinging, as before, to the left bank of the Illinois shore, as is shown particularly by the chlorine and nitrate determination."

"Table No. 152 (5938) contains the analyses of samples of water taken from the Missouri River at Fort Bellefontaine. The larger amount of suspended matter carried by the Mississippi River in high water periods is shown by these determinations, especially by the suspended residue on evaporation by the amount of oxygen consumed by suspended matter, and by the amount of nitrogen present in the form of albuminoid ammonia in suspended matter. Throughout the greater part of this

period, also, the number of bacteria in the Missouri River water was high."

"Tables Nos. 148-9-50-1 (5939 to 5942) contain analyses of water taken from the Mississippi River opposite the pumping station of the St. Louis waterworks at the Chain of Rocks from the same point as those for 1899. The considerable amount of suspended matter, as is shown by the residue on evaporation, which was present in the waters of the Missouri River at the inlet tower and in mid-stream at this point, when compared with the smaller amount of suspended matter in the Mississippi River above the entrance of the Missouri, indicate that the major part of the water entering the St. Louis intake during the period covered by these analyses was derived from the Missouri river rather than from the Illinois."

"Table No. 158 (5951) contains analyses of samples of water taken from the tap at St. Louis, Missouri. The larger amount of suspended matter in the waters of the Missouri River during the latter part of this period is reflected in the increased residue on evaporation in suspended matter in the tap water, although the reduction in passage through the settling basins is very great."

"Q. What do the tables and tables of averages read in the record by you show as to the purification of the waters of the Illinois River for the period of 1899, interpreting the sanitary significance of the different chemical and bacterial constituents which you have heretofore explained?

"A. From an examination and consideration of the tables of separate analyses and the tables of averages for this period, the period of 1899, it appears that the water in the Illinois and Michigan Canal at Bridgeport and at Lockport, as well as the water of the Desplaines River at Joliet and of the Illinois River at Morris, contained throughout this period a large amount of nitrogenous organic matter in the early stages of decomposition. It appears, also, from the large amount of chlorine present in these waters that the initial pollution of the Illinois River reached a considerable height during this

period. The large number of bacteria present in these waters shows that the substances capable of serving as food for these organisms were present in great abundance.

The tables and averages also show that by the time the Illinois River reached Ottawa, being some what diluted in the course by the purer water of the Kankakee, mingling with which is incomplete at Morris, a very great change has taken place in the composition of the river water, a change which is manifested especially by the diminution in the amount of albuminoid ammonia, by the increase in the amount of nitrites and nitrates, and particularly by an enormous and significant diminution in the bacterial content.

"The oxidation of the organic matter continues with the passage of the water down stream, and by the time the flow reaches Averyville, the amount of free ammonia is greatly diminished, as compared with the amount at Ottawa. The amount of albuminoid ammonia is diminished. The amount of nitrites is somewhat lower than it was at Ottawa. The amount of nitrates has greatly increased, while the bacteria which were present in such enormous numbers in the water of the upper Illinois have now sunk to a point where they can be compared with the number present in ordinary surface waters in the United States, and with the number present in the tributaries of the Illinois during this period.

"Below Averyville the Illinois River receives a large influx of polluting material from Peoria, with its stock yards and distilleries, which is evidenced by the increase in some of the significant constituents in the river water, notably in the free ammonia and the albuminoid ammonia and in the number of bacteria.

At Pekin some additional pollution is received, and the mingling of the Peoria sewage with the Illinois River water has become more perfect. From Pekin to the mouth of the river the purification follows a general progressive course until by the time the mouth of the river is reached at Grafton, the amount of free and albuminoid ammonia, the oxygen consumed

by the carbonaceous matter and the number of bacteria are again low, while the relatively large amount of nitrates bears witness to the practical complete oxidation of the enormous amount of organic matter with which the sewage was laden at Peoria, as well as that with which it originally set forth at Lockport. (5961.)

"Q. For the period of 1900?

"A. (5963) The conditions in the Illinois River during the larger part of the period covered by these investigations are shown by analyses of samples collected at the same points and under the same conditions as in 1899, the whole series of analyses from May, 1899, to the end of June, 1900, forming one continuous period.

"From April to June, 1900, analyses were made of the water from the Chicago Drainage Canal at Kedzie Street and at Lockport. These analyses show that, as compared with the conditions of the water in the Chicago River, considerable dilution has taken place, as witnessed particularly by the chlorine determinations, as well as by similar changes in the other constituents of the sewage.

"A mingling of the waters coming from the Chicago Drainage Canal at Lockport and from the Illinois and Michigan Canal at Lockport, with the waters of the Desplaines River, which is subsequently joined by the Kankakee, took place during this period. The first admixture of the waters of the Drainage Canal took place on the 17th of January, 1900, after the canal had been filled, and the gates finally opened.

"Examination of the separate analyses of the samples of water from the Illinois River at Morris, and also of the averages of these analyses, shows that the water of the river at this point was charged with organic matter; that it contained a large amount of nitrogen in the form of albuminoid and of free ammonia; that the amount of oxygen consumed was high, and that the number of bacteria was still large.

"The samples of water taken from the Illinois River at Ottawa during this same period showed that considerable puri-

fication took place between Morris and Ottawa, the amount of free ammonia and of albuminoid ammonia, and of oxygen consumed being diminished, and the number of bacteria being little more than one-fourth the number in the Illinois River at Morris during this same period.

"By the time Averyville is reached, the process of purification had proceeded still further, both free and albuminoid ammonia being notably lower than at Ottawa.

"At this station, also, the amount of nitrates was high, showing that considerable nitrification had taken place in the flow from the Chicago Drainage Canal to this point. The number of bacteria was not half as great as in the Illinois River at Ottawa during this same period.

"A further addition of polluting water took place at Peoria and Pekin, with the result that in the lower half of the river the process of purification had again to be completed. How complete this purification was may be seen from the determinations at Grafton for this period, the amount of free and albuminoid ammonia in the water and the amount of nitrates indicating that this purification followed a parallel course to the purification in the upper half of the river.

"This second period, the conditions in which have been just described, has been arbitrarily separated from the first period, namely, that for the months of May to December, 1899, but the analyses show plainly that the essential course of events in the water of the Illinois River is the same, whether a period of two months or five months, or fourteen months, be considered.

"In all cases the same phenomenon is noticed. The water at the outset highly charged with putrescible organic matter and laden with sewage material, regains, in the course of about 130 miles flow, the condition usually existing in surface waters in this country.

"The entrance for a second time into this stream of a large mass of polluting matter, an event that occurs at Peoria and Pekin, as heretofore pointed out, is followed by a second successful attempt on the part of the stream to purify itself of this added load.

"The self-purification of the Illinois River during the period covered by these analyses, extending from May, 1899, to the end of June, 1900, is notable in character and extent, both at high water and at low water, both at low temperatures and at high temperatures, and shows convincingly that under the *conditions prevailing in the Illinois valley during the period studied, the self-purification of streams is not an interesting biological myth, but an actual and definite occurrence.* (5965.)

"Q. Professor, while these tables have been presented as covering two periods of investigation, as a matter of fact the investigation covers one period, does it not?

"A. It certainly does. There was practically no break in the analyses as they were conducted in my laboratory from May, 1899, to the end of June, 1900, weekly analyses being made throughout this period, with a few exceptions." (Vol. 6, 5965.)

"Q. During this entire period, do your chemical and bacterial examinations disclose the presence at Kampsville of the sewage from Chicago, whether from the Illinois and Michigan Canal for the first part of this period, or from the Chicago main Drainage Canal for the second?

"A. They do not so far as the number of bacteria in the water is concerned, nor do they so far as the various chemical determinations of albuminoid ammonia, oxygen consumed, nitrites and nitrates are concerned. The large amount of chlorine that enters the Desplaines River along with the Chicago sewage is, however, permanent, and not being liable to destruction by various influences, as is the case with the nitrogenous organic matter and the bacteria that are added in the Chicago sewage, the (5969) chlorine manifests itself at Kampsville and Grafton, and even beyond, into the Mississippi River.

"Q. Does the presence of chlorine in the water of a river, in the absence of the other chemical ingredients or constituents of sewage, indicate of itself the presence of sewage pollution?

"A. In my opinion, the presence of chlorine under those conditions would be absolutely devoid of sanitary significance.

It would be possible for a stream in the condition that the Illinois River was in at Kampsville, to be passed around the world several times in a closed conduit, consuming years or decades in the process, without altering materially the amount of chlorine in the water, although it is my judgment that, supposing the water were at the outset injurious to health, in the course of such a passage, and in such a time, it would become entirely free from any injurious qualities it might have originally possessed." (Vol. 6, 5969.)

In addition to the weekly chemical and bacterial determinations made upon the waters of the Illinois River by Professor Jordan, he conducted other experiments, wherein he made hourly examinations of the water of the Illinois. The experiments which he made are as follows:

"Q. (5984) Did you make any hourly bacteriological survey of the water of the Illinois River below Morris?

"A. Yes, sir.

"Q. Please state when this survey was made and describe it in detail.

"A. I have made such examinations of the river between Morris and Ottawa, at Wesley City, and at Grafton.

"Taking first the determinations made on the Illinois River at Morris. Several series of observations were carried out at this point. The first of these was on October 7, 1899. The day was bright and sunny, the temperature of the air being 7 degrees centigrade at six o'clock in the morning, and reaching 20.5 by mid-day. A slight breeze ruffled the surface of the water in the middle of the day, but was at no time strong. The river was very low, the gauge reading for that day being five feet, and the current exceedingly sluggish.

"With a view to determining the distribution of bacteria in different portions of the Illinois River at this point, a cross-section was taken across the river from the right to the left bank; three samples being taken at approximately equi-distant intervals from one another and from the shores. The upper cross-section were taken at a point just above the Mazon

River, the lower about three-quarters of a mile below the mouth of the Waupecan Creek. This was at a dry period, and little, if any, water passed into the Illinois from these tributaries at this date. This stretch of river is almost exactly three miles in length. The rate of flow between the two points was determined by weighted floats and by the use of fluorescein solution, and was found to be very close to half a mile per hour.

"Four series of cross-sections at hourly intervals were taken at the upper station, which may be designated as Station A, and these were followed by a similar series at the lower station, Station B, beginning six hours later. These samples were plated immediately after collection, the plating being completed within the hour in each case."

Then follows the tables of determination, which appear on pages 5985 and 5986 of the printed record.

"Attention may be directed to the fact that between these collecting stations, a distance of three miles traveled by the stream on this date, in about six hours, a great bacterial diminution occurs. The chlorine determinations show that the mixing of the Kankakee water and the Desplaines water is very incomplete, both at the upper station, which is about nine and one-half miles below the junction of the rivers, and at the lower station as well. This is entirely confirmed by the bacterial count and turbidity cross-sections at the two points.

"It should be noted that the decline in the numbers of bacteria occurs in almost equal degree throughout the whole breadth of the stream, being as great along the highly polluted bank of the river as along the comparatively uncontaminated left bank.

"A second series of observation was carried out on November 9, 10 and 11, 1899, in similar fashion, upon a longer stretch of river. The distance between the regular collecting station at Morris and the regular collecting station at Ottawa is about twenty-four miles, and the rate of flow between these points averaged one-half a mile per hour at the time our observations were made. A point midway between Morris and Ottawa was

selected, near Seneca, and a three days' series of operations was planned.

"The sun was wholly obscured by clouds during these three days, but no rain fell."

The tabular form of which appears on page 5987 of the record.

"During this flow of twenty-four miles, therefore, the Illinois River became nearly free from the great mass of sewage bacteria with which it was originally laden. In fact, the bacterial content of the Illinois at Ottawa on this date was not greatly in excess of that of the local tributary streams.

"In connection with these series of bacterial determinations may be given the averages of the regular chemical determinations made at the laboratory in Chicago during the period between October 23d and November 20, 1899. These determinations, which follow, show that a considerable degree of nitrification takes place in the river between these two points, as witnessed by the increase in the amount of nitrites and nitrates, the diminution in free, and especially in the albuminoid ammonia."

The results appear on pages 5989 and 5990 of the printed record.

"This last series of determinations show that on May 24, 25 and 26, 1900, the mixing of the Kankakee and Desplaines Rivers at Morris was more complete than on November 9, 10, 11, 1899. They also show a smaller number of bacteria per cubic centimeter of the water at this time. A diminution in the number of bacteria, however, similar to that noted in the earlier series, takes place during the flow from Morris to Ottawa, and there are fewer bacteria per cubic centimeter, as shown by the colony count at Ottawa during this period in 1900, than in November, 1899.

"I see no escape from the conclusion that in this flow of approximately twenty-four miles, the Illinois River, which at Morris contained a large number of bacteria, in all probability derived more or less directly from the sewers of Chicago, freed

itself from these bacteria to a remarkable and impressive degree in a short distance and in a relatively short space of time. The probable reason for the high mortality among bacteria in this particular stretch of the river will be discussed in another connection.

"I should like to state that these three series of observations upon the water of the Illinois River between Morris and Ottawa are not the only series that I have made between May, 1899, and June, 1900.

"Q. What other observations have you made, Professor?

"A. I have made several other series of observations between Morris and Ottawa of the same character as those just described. The samples were collected in the same way, the experiments in each case being conducted by my chief assistant, Mr. Irons, and myself.

"Q. When were the subsequent experiments made?

"A. Between July, 1899, and June, 1900.

"Q. That is between Morris and Ottawa?

"A. Between Morris and Ottawa.

"Q. Can you give the dates?

"A. One of these was on September 2, 1899. I have memoranda of the others with my papers at the University.

"Q. Professor, will you describe how these samples were taken from which the foregoing analyses that have been introduced in evidence were made, and the conclusions drawn?

"A. These samples were taken from a row-boat. The floats and fluorescein introduced into the water were followed down stream in the boat, so that it was possible to determine very closely the passage of a given body of water from one point to another, the object of the experiment being to observe the changes in one and the same mass of water flowing from point to point. This was true of the collections of water samples made immediately below Morris; the collections made at Seneca, and at Ottawa, were also made from a boat at regular intervals, but the entire body of water was not followed the whole distance from Morris by boat, the approximate time nec-

essary for the passage of the water from Morris to Seneca and from Seneca to Ottawa being determined and hourly examinations made at the lower points.

"Q. Professor, did you make any cross-section experiments at Wesley City?

"A. Yes, sir. On several occasions cross-sections were taken at Wesley City, below Peoria, to determine the amount of mixing at this point.

"Q. When were these experiments made?

"A. One of these, of which I have a record here, was made on June 13, 1900. It gave the following result:

	Free Ammonia.	Albuminoid Ammonia.	No. of colonies per c. c.
Right bank	.504	.864	4,340,000
Center	.144	.248	40,000
Left bank	.168	.240	2,400

"This cross-section was not made by me personally, but by Mr. Irons, in pursuance of my directions.

"The large amount of pollution entering the river at Peoria on the right bank is clearly shown in this sample. The free ammonia, the albuminoid ammonia, and the number of bacteria per cubic centimeter being immensely greater than on the left bank of the stream. Slight changes in the position of sand bars and in the height of the water deflect the main mass of pollution now to one side of the stream, now to the other, and so lead to the sudden and marked fluctuations in the analyses which the detailed tables show to be so characteristic of the samples obtained from this point.

"Q. Did you make a cross-section investigation at Grafton?

"A. Yes; on a number of occasions, both in 1899 and in 1900, cross-sections were taken of the Illinois River at Grafton. These cross-sections at Grafton dealt simply with the number of bacteria per cubic centimeter. In general, it may be said that the results obtained from samples taken midway between the banks of the streams and the center were not materially different from those taken from the center of the stream, mixing the

bacteria, so far as these determinations go, being complete at this point. Slight variations were, however, sometimes noticed, the number being sometimes higher in the center than on the sides; sometimes higher on the sides than in the center.

"Q. What sanitary significance do you attach to the experiments conducted by you at Morris which have been testified to by you in evidence?

"A. These observations upon the bacterial content of the Illinois River between Morris and Ottawa indicate, in my judgment, that a very large proportion of the bacteria entering the Desplaines River from the Illinois and Michigan Canal and from the Chicago Drainage Canal do not survive to reach Ottawa. From a sanitary point of view this observation would seem to be of importance in that it renders less probable the passage of disease germs down the river, as far as this point. Since these sewage bacteria disappear in such numbers, it is, in my opinion, fair to assume that the various non-spore forming pathogenic bacteria entering the Chicago sewage, die out at least in the same proportion." (Vol. 6, 5984-5993.)

In addition to the chemical and bacterial determinations made by Professor Jordan, and the individual experiments heretofore cited, showing the self purification of the Illinois river from the Chicago sewage, both in 1899 and 1900 Professor Jordan made determinations upon the bacillus coli communis in samples of water collected at the same points as were the samples in 1899 and 1900 heretofore referred to, and these coli determinations were made covering the period from between May, 1899, and June, 1900.

The tables of coli determination, as prepared by Professor Jordan, appear at pages 6009 to 6038 of the printed record.

The conclusions which Professor Jordan draws from these tables are best stated in his own language, which is as follows:

"Q. Please explain what this table shows and its sanitary significance is?

"A. This table contains a summary of the results of the

colon determinations made upon the Illinois River at Averyville and Grafton, compared with the tributaries of the Illinois and with the Mississippi and Missouri Rivers.

"On comparing the number of days on which bacillus coli was found in one cubic centimeter samples of water taken from the Illinois River at Averyville, with those taken from the Illinois River at Grafton, from the Mississippi River at Grafton, from the Desplaines River, from the Kankakee River, from the Fox River, from the Big Vermilion River, from the Sangamon River, and from the Missouri River, it appears that so far as the colon content enables one to pass an opinion as to the sanitary quality of these waters the Sangamon River at Chandlerville is one of the more highly polluted streams.

"The Illinois River at Grafton, the Mississippi River at Grafton and the Missouri River at West Alton appeared to be on substantially the same footing with one another in respect to their colon content, while the Fox River contained a smaller proportion of colon bacilli than any of the streams under consideration.

"The Illinois River at Averyville compares in respect to its colon content very favorably with the Illinois, Mississippi and Missouri Rivers and is perceptibly less highly contaminated than the water of the Sangamon River at Chanderville.

"Summing up these facts in the second division of this table it is seen that samples of water taken on 69 different days from the Illinois River at Averyville and at Grafton contained bacillus coli communis on 39 days, while the various tributaries of the Illinois River, samples from which were taken on 69 days, contained colon bacillus on 36 days. Samples taken from the waters of the Missouri on 66 days contained colon bacillus on 44 days.

"It appears therefore from these tables, that if the opinion that I have expressed regarding the sanitary significance of the colon bacillus in water is correct, the water of the Illinois River at Averyville and Grafton was not materially different from what it would have been if the tributaries of the Illinois

exclusive of the Desplaines River and its sewage content, had alone fed the basins of this stream. The colon content of such a stream at Averyville and at Grafton would have been substantially what it is at present.

"Q. What sanitary significance do you attach to the tables of colon determination as presented in evidence by you, considering them as a whole?

"A. As stated in my testimony of yesterday, my experience leads me to adopt the view that the relative abundance of the colon bacillus in water affords the most satisfactory single analytical indication that sanitary science at present possesses as to the sanitary quality of a natural water.

"Basing my opinion upon this, I may say that I regard the relative abundance of colon bacilli in the water of the Illinois River at various points, and in the various tributary streams as furnishing a highly important clue to the freshness of the pollution entering, and the amount of real purification undergone by each stream. Considered from this standpoint the water of the Illinois River at Averyville and at Grafton is no more impure than the water in the principal tributaries of the Illinois, and certainly no more impure or dangerous than the water of the Mississippi River at Grafton, or the Missouri River at West Alton. The successive and striking diminution in the number of colon bacilli at various points along the Illinois River from Lockport to Averyville, is proof in my judgment of the occurrence of a process of genuine self purification.

"Q. What sanitary significance do you attach to your chemical, bacteriological and colon determinations heretofore introduced into evidence, as evidenced by the tables introduced for the period extending from May, 1899, to the end of June, 1900?

"A. I regard these determinations as forming a connected and correlated whole, mutually sustaining one another, and all pointing in my judgment, to but one interpretation. The oxidation of the organic matter that was introduced in enormous quantities at Lockport, the more or less complete destruction of

the sewage bacteria also introduced at this point, and especially the high mortality among the colon bacteria occurring in the upper stretches of the river, all appear to me to indicate that infectious matters that might have been introduced into the sewage of Chicago and found their way into the Drainage Canal during this period from May, 1899, to the end of June, 1900, did not make their way down the river so far as Averyville. So far as my interpretation of the results of the chemical analyses, the bacterial counts and the colon determinations is concerned, I have no hesitation in expressing as my opinion that the water of the Illinois River at its mouth is no more liable to convey disease or to produce injurious consequences of any kind than the waters of the Mississippi River at this point, or the water of the Missouri River at West Alton. In expressing this opinion I am taking into consideration all the knowledge that I have acquired by personal experience and all the information that I have obtained regarding the chemical and bacterial content of these waters during the period under consideration. (Vol. 7, 6038-6040.)

"Q. What sanitary significance do you attach to your chemical and bacterial analyses, including the colon tests, colony counts and species determinations heretofore introduced into evidence, as evidenced by the tables and charts and photographs already introduced by you?

"A. Taking into consideration all the analytical data that I have obtained throughout the seventeen months covered by the investigations, I conclude that one of the most remarkable facts, if not the most remarkable, is the entire concurrence of the results derived from the chemical and the various bacterial determinations. The amount and rate of nitrification in the water of the Illinois River at various points along its course, as shown by the tables of chemical analyses, are in line with what the experience of water analysts has shown to accompany a real purification. The large amount of organic matter present in the upper stretches of the Illinois River is oxidized during its passage down stream, and before Averyville is reached the ni-

trification of this organic matter has progressed practically to completion.

"On the bacterial side, the evidence is wholly confirmatory of this improvement in the quality of the Illinois River water. The enormous number of bacteria poured into the Illinois River in its upper stretches, as shown by the number of bacteria present in the Illinois River at Lockport and Joliet, is greatly diminished in a flow of less than one hundred miles. Under certain conditions even, and at certain periods of the year, the Illinois River becomes nearly free from the great mass of sewage bacteria with which it was originally laden in as short a distance as twenty-four miles, as evidenced by the observations between Morris and Ottawa, already introduced. Both at Averyville and above Grafton the bacterial composition of the Illinois River water is about the same as that of tributary streams and as that of the Mississippi River just above Grafton. The colon content of the Illinois River water is, in my opinion, especially significant from a sanitary point of view, and affords evidence in entire harmony with the conclusions derived from the chemical examinations and from the number of bacteria of all kinds shown to be present in these waters. The colon bacteria which are found in great abundance in the waters of the Drainage Canal and in the upper stretches of the river practically disappear before Averyville is reached.

"It is clear from the data that I have presented that the water of the Illinois River undergoes a real and very considerable purification. The colon bacteria which are shown to be present in large numbers in Chicago sewage disappear almost completely in less than 150 miles flow. At the mouth of the Illinois River, despite the enormous initial pollution and the very large secondary pollution at Peoria, the number of colon bacteria is certainly no greater than the number in the Mississippi River at this point, and not as large as the number in the Missouri River at Bellefontaine. Since all investigators are agreed that the colon bacillus is more hardy than its relative, the typhoid bacillus, and can live in water for a longer time, there

is every reason for supposing that the latter microbe dies out with at least the same rapidity. If it be true, as I firmly believe to be the case, that the fate of the colon bacillus in running water furnishes the most satisfactory indication we can secure at present of the continuance of vitality of the typhoid bacillus, there can be no hesitation as to the conclusion to be drawn from this investigation. Since this biological relative of the typhoid bacillus perishes speedily and in large numbers in the course of the Illinois River, it is my opinion that the typhoid bacillus itself cannot long survive exposure to the same conditions." (6138.)

Professor A. W. Palmer, who made chemical surveys of the Illinois River in 1896, 1897, 1898, 1899 and 1900, and submitted in evidence the tables of analyses and tables of averages (5374), testified in part as follows:

"Q. Now, what significance do you attribute to these tables, and the tables of averages to which you have just referred and which you have read in evidence?

"A. Morris is the first station upon the Illinois River proper. At this point the waters of the stream consist of an incomplete mixture of the sewage-laden waters of the Desplaines River with the waters of the Kankakee. Prior to the opening of the Drainage Canal the Chicago sewage discharged into the Desplaines River experienced no considerable dilution before getting the waters of the Kankakee, except when the Desplaines itself was in flood. This, however, was rarely the case at times other than those of the usually short spring freshets. When the Kankakee was in flood, the dilution at this point was, of course, correspondingly great, as much as fifty to one; the average dilution for the year being about ten to one, but ordinarily in the summer and autumn the dilution would probably rarely exceed two or three to one, and often fall far short of this. Since the opening of the Drainage Canal the flow in the lower Desplaines is far more uniform and the average is just about equal to the average flow of the Kankakee, which is about 300,000 cubic feet per minute.

"Q. The volume of water therefore added after the opening of the canal to the stream was as great as the volume which existed before at the mouth of the Desplaines River?

"A. Yes, but the average through the two canals is much more uniform throughout the year, while the figure referred to with respect to the Kankakee is an average for the year, and includes volume ranging from a very small minimum flow elsewhere stated in the testimony, and the exceeding great flow of the spring freshet. That is to say, the volume from the Kankakee varies greatly at the different seasons, while the flow in the Desplaines, due to the discharges from the main drainage channel and the Illinois and Michigan Canal is fairly uniform throughout the year, considering the details of the analyses which appear in tables 17 to 20 inclusive, considerable variations appear which, however, are not entirely due to variations in the volume of water flowing, but are in part due to the fact that at this point the mixing of the waters from the two general sources, namely, the Desplaines River and the Kankakee River, are quite incomplete, so that individual analyses consequently appear to vary considerably more than the mean composition of this incomplete mixture warrants, but it is not likely that the variations thus occasioned are for this point sufficiently great to seriously affect the yearly averages and the comparisons instituted between them. * * * The averages for the year 1897, which appear in table No. 17, averages for the year 1898, the detailed analyses for which appear in table No. 18; averages for the year 1899, the detailed analyses for which appear in table No. 19, and averages for the year 1900, the detailed data for which appear in table No. 20, so we have thus averages for four years preceding the opening of the main drainage channel, and for one year subsequent thereto. The two general averages made up from these yearly averages, and hence representing the four-year period before the opening of the Chicago main drainage channel, are as follows:

	Average for 4 years before 1900.	For 1900
Chlorine	44.4	23.1
Oxygen consumed	15.6	12.3
Oxygen consumed by dissolved substances	11.2	6.7
Oxygen consumed by suspended matters	4.1	5.6
Nitrogen as free ammonia	5.585	2.075
Nitrogen as albuminoid ammonia, total	.97	.535
Dissolved	.499	.269
Suspended	.387	.2666
Total organic nitrogen	1.8625	1.162
Organic nitrogen in dissolved matters	1.05	.631
Organic nitrogen in suspended matters	.756	.531
Nitrogen as nitrites	.0965	.108
Nitrogen as nitrates	1.0665	.717

* * * * * * * * *

"It is evident that at this point the proportions of chlorine and of organic matters as represented by the oxygen consumed and nitrogen in the form of free ammonia and albuminoid ammonia, the total organic nitrogen, have been considerably less in the waters of the Illinois in the year 1900 than they were during the four preceding years. On the other hand, the nitrogen as nitrites was present in the water of the Illinois River at Morris in more considerable proportion in the year 1900 than in 1899, but less than it was on the average during the four preceding years.

"Nitrogen as nitrates was present in greater proportion in the year 1900 than in the year 1899, or the average for the four years preceding the opening of the Chicago Drainage Canas was greater than the proportion contained during the year 1900.

"The nitrites in the waters of the Desplaines River at Joliet have been considerably greater in proportion since the opening of the Chicago drainage channel than they were prior to that opening, and the same is true at Morris. It is evident, then,

that such agencies as bring about the oxidation of the organic matters through ammonia to nitrites, and finally to nitrates, are fully as effective since the sewage has been more extensively diluted at and near Chicago. The fact that the nitrites are now found in greater quantity at Joliet and at Morris indicate that the nitrifying action going on in the river is more active at a point nearer to Chicago; that is, that the oxidizing influences that work upon the organic matters in the waters of these streams are more efficient now nearer to Chicago, this undoubtedly being one of the results of the greater dilution of the sewage with comparatively purer and oxygen saturated Lake Michigan water. (5378.)

"The analyses show the changes which take place during the flow of 24 miles from Morris to Ottawa, without further dilution and without notable addition to impurities, but the mixing of the discharges from the Desplaines and the Kankakee is not yet complete at this point, and some of the variations of the individual analyses are due to this cause. It is to be noted that at this point the nitrites are found in the waters of the Illinois River in greater proportions than at any other point along its course, which fact taken into consideration with the other indications of the analyses, shows that it is in this stretch of the river that the final oxidation processes which convert the organic matters of the sewage into innocuous mineral substances, the free ammonia, the nitrites and the nitrates and so on, are most active and effective. (5380.)

"Comparison of the averages for the Illinois river at this point for 1899 with those for 1900, and the few for 1901, show how great was the dilution effect of the flow of the Chicago main drainage channel, thus the chlorine for the year 1899 averaged 59.5—this is at Morris—while for the year 1900 it was 21.3. The total oxygen consumed was in 1899, 11.3; in 1900, 8.6.

"Oxygen consumed by dissolved substances in 1899, 10.5; in 1900, 6.9.

"That required by suspended matters was in 1899, 1.13; in 1900 it was 1.7.

"The free ammonia during the year 1899 averaged 4.99; in the year 1900 it was 1.311.

"Nitrogen as albuminoid ammonia, total, for 1899, the average was .498; for 1900, .39.

"The albuminoid ammonia derived from dissolved substances was, in 1899, .399; in 1900 it was .244.

"The albuminoid ammonia from suspended matters was, in 1889, .0997; in 1900 it was .147.

"The total organic nitrogen was, in 1899, on the average, 1.111; in 1900 it was .848.

"The organic nitrogen in dissolved matters was during the year 1899 .824, and during 1900 was .537.

"Organic nitrogen in suspended matters was in 1899 .287; in 1900, .311.

"Nitrogen as nitrites, in 1899 the average was .495; in 1900 it was .25.

"The nitrates in 1899 were 1.857, and in 1900 were 1.62. (5380-81.)

"It is very noticeable that both before and since the opening of the Chicago main drainage channel the proportions of free ammonia are much greater in cold weather than in other seasons, and it is evident, too, that the proportions of free ammonia content in the water of the Illinois River at Averyville are much less since the opening of the Chicago main drainage channel than they were before that time. (5386.)

"Comparison of the averages for Averyville with those for the tributary streams serves to show that the waters of the Illinois River at this point contain considerably less organic matters than are contained in the waters of its chief tributaries, which latter have never been in contact with Chicago sewage although, of course, they receive some sewage from comparatively small towns. It is very evident, of course, that free ammonia and nitrites are still present in the waters of the Illinois River at this point in greater quantities than are contained in most of the tributary streams, but the considerations detailed above and all available data show unmistakably that

the character of the water in the streams at Averyville is now far better than it was before the Chicago sewage received its initial dilution at Chicago, and not at the junction of the Desplaines and Kankakee Rivers, sixty miles nearer to the point now under consideration.

"It is my opinion that the *animal matters* discharged by the two canals, the Chicago main drainage channel and the Illinois and Michigan Canal into the Desplaines River in the vicinity of Lockport and Joliet, and discharged by the Desplaines into the Illinois River about ten miles above Morris, *have been entirely destroyed before the waters of the Illinois River reach Averyville*, and the substances of said animal matters have been in part converted into mineral substances, and in part built up into the substance of living vegetation, this opinion being based upon my study of the waters of the streams in question, at the various points enumerated in my testimony in this case, and upon the evidence of the chemical analyses which have been introduced as part of my testimony." (5390.)

"The evidence shows conclusively that since the opening of the Chicago main drainage channel there has taken place not only a considerable diminution in the proportions of the organic matters contained in the waters of the lower Illinois River, and as they are about to discharge from that stream into the Mississippi, but that a substantial decrease of the actual quantities of the organic matters contained in these waters has occurred, and this notwithstanding the fact which I have testified to already, that the quantities of organic matters conveyed in Chicago sewage into the Desplaines and thence into the upper Illinois are considerably greater now than they were before the opening of the Chicago main drainage channel. As it has been shown in my testimony that the organic matters contained in the Chicago sewage discharged into the upper Illinois are practically destroyed or converted into vegetable matters by the time the waters reach Peoria, that is Averyville, where another great influx of sewage and other organic waste occurs, it will be of importance to compare the condition of the

water at Averyville, just above Peoria, with its condition at Kampsville, 140 miles below, with respect to the quantities of organic matters carried by the stream at these two points. (5622.)

"The data involved in this comparison have been brought together upon table 15 of this series, which is as follows: (5623.)

"Table 15 represents the quantities of nitrogen in the waters of the Illinois River at Averyville, above Peoria, tons discharged per 24 hours; that is, the average for the years 1897 to 1901 inclusive, with the general averages, first, for the three-year period before the opening of the Chicago main drainage channel, and, second, for the two-year period immediately following, and also there are introduced here once more, for purposes of comparison, similar data with respect to Kampsville.

"Comparing the averages for the three-year period before the opening of the Chicago main drainage channel with the averages for the two-year period subsequent thereto (and I may say here that no analyses of the waters of the Illinois River at Kampsville were made by me for the year 1902, the work at that point was discontinued), comparison of the general averages for these two periods shows that subsequent to the year 1899 there was a decrease in the weight of nitrogen as nitrites as discharged by the waters of the Illinois River at Averyville from 5.24 tons per 24 hours to 2.34 tons per 24 hours, a decrease of 55 per cent.

"The nitrates, on the other hand, were increased, the increase amounting to 16.85 per cent.

"The nitrogen as free ammonia showed a very considerable decrease, amounting to 22.9 per cent., the total organic nitrogen Kjeldahl, show a decrease amounting to 17.86 per cent.

"The total nitrogen, that is, the sum of those before referred to, shows a decrease of 6.26 per cent.

"The nitrogen as albuminoid ammonia decreased in quantity 32.78 per cent.

"The oxygen consumed by the waters of the Illinois at this point showed a decrease amounting to 25.55 per cent.

"Comparing the data for Averyville with those for Kampsville for the years 1897 to 1899 inclusive, the data for Kampsville having been taken from the tables heretofore introduced in evidence by me, shows that between Averyville and Kampsville there is a very considerable decrease in the quantities of nitrites carried by the waters of the Illinois River, this amounting to 48.47 per cent.

"That the nitrogen as nitrates during this period increased 14.5 per cent.

"The nitrogen as free ammonia decreased 43.56 per cent. The total organic nitrogen as determined by the Kjeldahl process, increased 62.15 per cent., this increase being due to the organic matters brought in by the various tributaries of the Illinois, the discharges of organic matters at Peoria and Pekin and the wash from the immediate watershed of the river, and including the vegetation of the river which has subsisted upon refuse organic matters, introduced at points above and from the conversion of mineral matters contained in the water, including nitrates, nitrites, free ammonia, carbon and so on, into the substances of the vegetation which is so luxuriant in the lower reaches of the Illinois, the total nitrogen is found to increase 7.47 per cent. during this period between Averyville and Kampsville.

"The albuminoid nitrogen increased between these two points to the extent of 44.39 per cent., considerably less in proportion than did the total organic nitrogen.

"The oxygen consumed by the waters increased in quantity between these two points to the extent of 45 per cent.

"Comparing the period after the opening of the Chicago main drainage channel and for the purpose of putting this comparison upon a more reasonable basis, I have calculated an average for the content, that is, the quantity of these constituents contained in the waters of the Illinois River at Kampsville for the two-year period following the opening of the Chicago main drainage channel, since we have data for Averyville only for this period, we find generally as follows:

"A decrease in the quantities of nitrogen as nitrites from 2.34 tons per 24 hours at Averyville to 1.22 tons per 24 hours at Kampsville, a decrease of 47.85 per cent., which is almost as considerable in percentage as the decrease between these two points in the early years, while the actual quantities themselves are about one-half the quantities contained in the water at these two points during the previous period, that is, the three years prior to the opening of the Chicago main drainage channel. The nitrates show a change between Averyville and Kampsville, that is, a decrease amounting to 5.49 per cent., while in the former period between these two points there occurred an increase in the weights of nitrogen as nitrates. The nitrogen as free ammonia were for Averyville during this period 18.88 tons per 24 hours, the quantities for Kampsville being 11.24 tons per 24 hours, showing a decrease of 40.46 per cent. between the two points, which is practically the same as the decrease which took place between these two points during the previous period, which was 43.56 per cent, while the actual quantities contained at both points in the second period were considerably less than they were in the earlier period. (5625.)

"The organic nitrogen as determined by the Kjeldahl process, increased between these two points in this period from 20.38 tons per 24 hours to 27.43 tons per 24 hours, showing an increase of 31.37 per cent., which is but little more than one-half as much as the increase which took place between these two points in the period of three years prior to the opening of the Chicago main drainage channel. The figure for that period being an increase of 62.15 per cent.

"The total nitrogen contained in the waters shows a decrease of 5.16 per cent. in this period as against an increase of 7.47 per cent. during the earlier period.

"The albuminoid ammonia shows an increase of 25.03 per cent. as against an increase of 44.39 per cent. during the earlier period, the oxygen consumed showing an increase of 27.68 per cent. as against the increase of 45 per cent. during the earlier period.

"The data of this table No. 15, of this series, show that the condition of the water of the Illinois River just above Peoria is very much better since the opening of the Chicago main drainage channel.

"The data of this table No. 15 of this series corresponds completely with the data of the various tables I have introduced in evidence, in showing that the condition of the water of the Illinois River just above Peoria is very much better since the opening of the Chicago main drainage channel, and that the natural destruction of the organic matters discharged into the river in the sewage is, by the time the water reaches Averyville, far more complete than it was at this point prior to the year 1900.

"A comparison of the data for Kampsville with those at Averyville shows that at the like periods which have been referred to (and no examinations of the water at Averyville were made in 1902), the actual weights of the nitrites and of free ammonia carried by the water of the Illinois decreased more than 40 per cent. during the flow from Averyville to Kampsville, inasmuch as the waters of the tributaries of the Illinois contained organic material in proportion equal to those of the Illinois itself, and since enormous quantities of nitrogenous organic matters are discharged into the Illinois at Peoria and Pekin, a few miles below Averyville, a considerable increase in the quantities of nitrogenous organic matters in the waters of the lower Illinois might well be expected, but it is to be remembered that the organic matters in the waters of the Illinois below Havana, 45 miles below Peoria, and 88 miles above Kampsville, consist of vegetable matters, chiefly those of the Plankton, as is shown both by observation and by the results of the general investigations which have been introduced in evidence. (5627.)

"Q. Taking into consideration the conditions which exist upon the watershed of the Illinois River, and also the numerous chemical analyses of the waters of the Illinois River which you have made and about which you have testified in this case, what

effect, in your opinion, has the opening of the Chicago Drainage Canal, in January, 1900, had upon the waters of the Illinois River, and especially upon those waters at Averyville, just above Peoria, and at Kampsville, near the mouth of the river, and at Grafton?

"A. Taking into consideration my knowledge and information concerning the Illinois River, its tributaries, its watershed and the conditions prevailing upon and along the same, and taking into consideration the chemical examinations that I have made of the waters of the stream and of its various tributaries, both before and after the opening of the Chicago main drainage channel, *it is my opinion that the effect of the greater discharge of water resulting from the operation of the Chicago main drainage channel has greatly improved the conditions of the water of the Illinois River, all along its course, rendering its waters less offensive to the senses in the immediate neighborhoods of the point of discharge of Chicago sewage into the Desplaines and thence into the Illinois, and reducing the proportions of the organic matters contained in the waters of this stream at Averyville and at other points along its course, and reducing the proportions of nitrogen as free ammonia and as nitrates, and reducing also the quantities of nitrogen as ammonia and as nitrites contained in these waters, and in reducing not simply the proportion, but reducing also the actual quantities of the nitrogenous organic matters contained in the waters of this stream at various points, and particularly at Averyville*, to all of which I have testified heretofore, in the evidence I have presented in this case, and with respect to Kampsville I may refer to my testimony given above in this case, and state it as my opinion here, based upon the considerations enumerated above, that the condition of the water at Kampsville has been greatly improved, co-incident with and as a consequence of the operation of the Chicago main drainage channel, in that my evidence shows a great reduction in both the proportions and the actual quantities of the most significant constituents of these waters

as determined by the sanitary chemical analyses. And I base this opinion further upon the fact that since the opening of the Chicago main drainage channel or sanitary canal, although the quantities of organic matters in the sewage now discharged into the Desplaines and thence into the Illinois River, are 30 per cent. greater than before that opening, the proportions of organic matters contained in the waters discharged by the Illinois River into the Mississippi are considerably smaller than they were prior to 1900; and that this decrease of the proportions is not a mere dilution is shown by the fact testified to by me, that the actual quantities of organic matters discharged are now less than they were formerly." (5641.)

Professor Thomas J. Burrill, of the University of Illinois, after he had introduced his tables and charts of bacterial examination, was asked this question:

"Q. Professor, will you explain the significance of the variations in the number of bacterial counts at the various places indicated in the series of tables which you have just explained, beginning with table 21 and ending with table 28?

"A. These tables present in a graphical way the very great difference in the number of colonies of bacteria found in our test plates made from water taken at these different places. It will be seen that without exception these numbers are very large, from the waters taken from the Illinois and Michigan Canal at Lockport, from the Sanitary Canal at Lockport, from the Desplaines River at Joliet, throughout the time that the examination was made. At Morris also the plates show that the number was very large, yet a considerable decrease from those at the places just mentioned, in most cases, though in the showing for August, 1899, the number is nearly as large as we find it to be at any of the places. This indicates to me that the waters through this course of the stream have in them great quantities of decomposable organic matter suitable for food for these organisms, and that the other conditions are such that the latter multiply enormously in these waters; but between Morris and Ottawa the indications are from these plates, that a great

change takes place; that the numbers of bacteria are greatly decreased. This decrease is out of all proportion to the increase of water received by the stream during this time, or, in other words, the amount of dilution that the stream has after passing Morris. This decrease in the number is maintained with some irregularity to Averyville, where the number found on an average equals that of ordinary river water, not especially subject to contamination. This seems to be true in every case, as shown by the plates for the condition of things in the Illinois River at Averyville.

"Q. State whether the bacterial counts at Averyville indicate whether or not the effect of depositing of the sewage of Chicago into the Desplaines and Illinois Rivers has already soon disappeared?

"A. This showing seems to prove that the pollution of the water at Bridgeport, and subsequently near the head waters, has practically disappeared at Averyville. (pp. 5748.)

"Q. And what do they indicate further down at Grafton, so far as the additional contribution of pollution is concerned?

"A. The plates taken together show very conclusively great pollution of the stream below Averyville, but that the organic matter is largely absent in the course of the stream after it reaches Havana, and especially so at the mouth of the Illinois at Grafton." (5749.)

And again Professor Burrill says:

"In my opinion, the very decided reduction of the number of the bacteria found in the course of the stream up to the time the waters reach Averyville, causing the waters at this place to assume the character of a normal river water, indicates that the contamination from the sewage introduced into the stream from Chicago have disappeared at this point, and I cannot otherwise than conclude that the evidence now presented shows that the water at the mouth of the Illinois River at Grafton is practically free from any such contaminations introduced at Chicago. (5759.)

In the testimony of Professor Gehrmann, who made a bacte-

rial examination of the waters of the Illinois River for the period in question, he states as follows:

"I can say that from the examination of the samples and the number of bacteria found, that there is a point at about Averyville where the condition as to the number of bacteria exists about equal to that of the tributaries of the river, and that the waters here show the least numbers of bacteria in the course of the river to the point at which they increase next below. I should therefore say that a degree of purification had taken place at about the location of Averyville in the river." (4815.)

"The waters of the Illinois River at Grafton, after it had received the enormous pollution from the City of Peoria, and its cattle sheds, by the time it reached Grafton, had assumed the same condition of bacterial purity that it had at Averyville, above Peoria." (4817.)

Professor John H. Long, who made a chemical survey of the river before and since the opening of the Chicago Drainage Canal, from samples of water taken at different points in the river from those which were taken by Professors Jordan, Gehrmann and Palmer (the chemical results of his analyses having been introduced in evidence and appearing in the testimony in this case), was asked this question with respect to the period of 1899:

"Q. From a consideration of these tables of analyses as introduced by you, and the table of averages drawn from these tables of analyses, what conclusions do you draw as to the waters of the Illinois River? (4159.)

"A. From a consideration of the tables presented and from the tables of averages drawn from these individual tables, these general conclusions may be reached:

First: That the first and most general examination of this table shows a very great diminution in the organic pollution of the Illinois River and its tributaries, and the source between Bridgeport and upper Peoria or Averyville, a diminution of the organic matter which cannot be accounted for by the dilu-

tion from the tributary waters as shown approximately by the decrease in the chlorine contents. This decrease in organic matter is explained by a consideration of several factors. We find in considering the data given for oxygen absorption or oxygen consumption in the filtered water as well as in the unfiltered water, that between Bridgeport and Peoria there is a very marked decrease, a point being reached finally where the organic matter as disclosed by the oxygen consumption test does not appreciably differ from that found in the tributaries of the Illinois as shown by the same test. I find also a very marked decrease in the amount of the product indicated by the albuminoid ammonia, a decrease from over three parts per million to .57 parts per million. This last amount being not a great deal different from that found in several of the tributaries of the Illinois. I find also in considering this table a very marked change in the decrease in the amount of the so-called free ammonia, the decrease here being very nearly from twenty parts per million to less than one part per million, this decrease being in a measure, an index of the extent of bacterial oxidation or purification which has taken place in this part of the stream. We observe also in the figures showing the amount of nitrogen present in the form of nitrates, that a very great oxidation has taken place in the Illinois River, the nitrates resulting from the bacterial oxidation of the nitrogen which has previously existed in some other form and which has gone through the stage of free ammonia. We observe also the appearance of nitrites in considerable amounts in the lower stretch of this part of the river. The nitrites indicating also the advance of oxidation. A very noticeable feature of these tables is that after upper Peoria or Averyville, or the Peoria Narrows is passed, the condition of the river as disclosed by the analyses shows a very marked organic pollution again. We find that below Peoria the amount of organic pollution as measured by the albuminoid ammonia is very nearly as great as that observed in the Canal at Bridgeport. We find also in passing Peoria that the free ammonia has increased from

less than one part per million to over four parts per million. We find also that the figures measuring the oxygen consumption in passing Peoria have increased in the case of the unfiltered water from over six parts per million to over seventeen parts per million, and the figure indicating the oxygen consumption in the filtered water has increased approximately from five and one-half parts per million to nearly thirteen parts per million. This remarkable increase in the numbers given shows that at this point a very great amount of organic matter has been added to the Illinois River. From the investigations which I have myself made at different times, an explanation of this increase is given. It is a matter of personal investigation, and also of common knowledge that in the City of Peoria there are great industries which discharge waste of a highly organic nature into the Illinois River, and the samples of water collected at Wesley were taken from a point below the discharge of these industries. These industrial wastes are mainly from distilleries and from cattle sheds in which cattle feeding on the slops of these distilleries are kept, and from glucose factories. Coming down the river from Peoria we observe again as we did in coming down from Bridgeport to Peoria, a very marked gradual decrease in organic contamination. This decrease is observed in a gradual fall in the figures indicating the oxygen consumption in the filtered and unfiltered water and in the free ammonia and in the albuminoid ammonia, so that a change takes place in the Illinois River below Peoria, and is due to the same general causes, as indicated by the amount and character of the products given here, as takes place in the river above Peoria, so that finally, at the mouth of the river at Grafton, we have reached a condition in which the factors for organic pollution are not greatly different, or essentially different, from those observed in the tributaries of the Illinois River. Taken as a whole, then, these tables disclose two main sources of contamination of the Illinois River; first, the sewage from the City of Chicago which decreases very greatly before Peoria is reached, and secondly, the industrial

wastes from the City of Peoria which decrease greatly before the mouth of the river at Grafton is reached. A consideration of these figures shows beyond any question whatever that the main factor in the contamination of the Illinois River at its mouth is not the waste or sewage contributed from Chicago, but the industrial waste contributed from the various industries of the City of Peoria." (4162.)

"Professor, you have testified as to the chemical results of the 1899 investigation. What does the bacterial result, such as you explained that you made this morning, disclose as to the quality and conditions of the waters of the Illinois River and its tributaries? (4169.)

"A. These bacterio-chemical results agree in a general way with the chemical results, in showing the condition of extreme organic contamination at Bridgeport, Lockport and Joliet, which show gradual improvement as we go down the river until Peoria is reached,—upper Peoria or the Narrows, or Averyville, as it is called, where the individual results obtained by the various methods which I referred to this morning do not differ essentially from similar results obtained from the tributaries of the Illinois. But leaving Peoria Narrows and going down to Wesley, we find as indicated by these bacterio-chemical results, great and marked increases of contamination again. The number of forms of organic matter in the organized condition, or living condition at Lower Peoria or Wesley as disclosed by what is called the colony count, is certainly as great as that found at Bridgeport, while the factors indicating the fermentation of carbohydrates by the bacteria present, and indicating the presence of those bacteria which convert carbohydrates into acids and coagulate milk are likewise as great at Wesley as at Bridgeport, so these bacterial results then in general, agree with the chemical results in showing an enormous increase of pollution, as Peoria is past, and these chemical bacterial results show as we leave Peoria and go down the river, a gradual diminution in the organized forms until the mouth of the river is reached at Grafton, where the

number of bacteria present and the behavior of the bacteria with the reagents mentioned, show a condition similar to that found in many of the tributaries of the Illinois." (4170.)

Also in 1900, after having introduced in evidence tables of analytical data, together with the average for the spring work of 1900 (which appears in Professor Long's testimony), he was asked this question:

"Q. From this table of averages which you have just read, and the analytical tables which have been read by you, what conclusions are you able to draw from the tables thus presented, as to the condition of the water in the Illinois River during this period, at these various points? (4180.)

"A. From these various tables I note that the amount of organic matter at Bridgeport in the old Canal and the Drainage Canal at Western Avenue is less than disclosed by the previous analyses given in 1899. An exact comparison is, however, difficult because of the fact that in this period, in the spring of 1900, the water flowed through both canals, through the Illinois and Michigan Canal and through the Drainage Canal, but not at a constant rate, so that an exact comparison of these figures is difficult. However, as we proceed down the river to Morris, where there is a complete mixing of the waters, we find for the numbers representing the free and albuminoid ammonia a lower amount than disclosed in the analyses made in 1899. When lower Peoria or Wesley is reached, there is here a very great increase in the figures for all constituents. In the factor representing the oxygen absorption, the free ammonia and the albuminoid ammonia the increase is very marked. Following below Peoria, we observe a decrease in these factors, representing or pointing to the amount of organic matter present. We find at Pearl that the factors for oxygen consumption and for albuminoid ammonia are as low as in the 1899 examinations in general, and as low as disclosed in the waters of many of the tributaries of the Illinois. We find at Grafton, however, below Pearl, for some reason which cannot be given, a slightly larger amount of organic matter in the

mean, than at Pearl, but the point of greatest importance in this table is the very marked increase of the organic matter at Peoria and at Wesley, the point below Peoria, as compared with the amount found at points above during this same examination. (4182.)

"Q. What was the condition at Wesley in 1900 as compared with 1899?

"A. At Wesley in 1899, in the mean, as indicated by the albuminoid ammonia there was more organic matter present than in 1900, as indicated by the oxygen consumption; also somewhat more in 1899 than in 1900. The free ammonia at Wesley in 1899 is greater than that at Wesley in 1900." (4183.)

"Q. What was the condition at Havana during those two periods?

"A. At Havana, in 1899, the amount of organic matter as measured in parts per million by the free and albuminoid ammonia, was greater than in 1900, and the oxygen consumed shows a somewhat similar condition. The oxygen consumed is a little greater in the spring of 1900 than in 1899." (4183.)

"Q. What was the condition at Pearl during these two periods?

"A. As measured by the oxygen consumption, the organic matter in parts per million is greater in 1900 than it is in 1899, but as measured by the albuminoid ammonia present, the contamination in 1899 is greater than that in 1900." (4184.)

"Q. From the analyses made by you in 1900, and the table of averages read by you for that period, what do your analyses show the condition of the Illinois River and its tributaries to be as to pollution from Bridgeport to Grafton?

"A. These tables considered in comparison with each other, and a consideration of the averages of the tables for the work of the summer of 1900, show in general, to begin with, a lower initial contamination of the water at Bridgeport than was the case in the examinations of the waters made in the previous year, 1899. The tables show further, as we proceed down the river and canal from Bridgeport to Lockport and

Joliet, and down the Illinois River proper a gradual and continuous diminution in the factors indicating the organic contamination, and to an extent which is very much greater than can be accounted for in any way by the amount of dilution coming in from the tributaries. An examination of these tables shows first, in general, a marked reduction of organic matter as compared with the amounts present at the source of contamination,—Bridgeport, in the main Drainage Canal. At the Narrows above Peoria, the factors indicating the extent of organic pollution as drawn from the results of the oxygen consumption test and the free and albuminoid ammonia tests are not greater than those found from an examination of the ordinary tributaries—from the ordinary tributary waters of the Illinois in this State. (4208.)

"We find also on further consideration of the table that after Peoria Narrows is passed and the next point is reached, a remarkable increase in the organic pollution again, as measured by the important factors already referred to, the oxygen consumption and free and albuminoid ammonia, this increase being in the free and albuminoid ammonia several hundred per cent. The figures for oxygen consumption increase are likewise very large. The increase, from the known nature of the contaminating material entering the river at Wesley, is largely nitrogenous, and hence the much greater increase apparent in the figures for free and albuminoid ammonia than that apparent in the figures for oxygen consumption. Below Peoria as we proceed down the river we observe a decrease again in these figures,—a decrease in the oxygen consumption by the waters, a decrease or disappearance of the free ammonia and a very marked decrease in the albuminoid ammonia at Pekin. At the points below Pekin there is but little further decrease in the albuminoid ammonia for the reason that we have reached here a condition in the amount of albuminoid ammonia which is comparable with that found in the ordinary rivers of the State, beyond which the reduction does not commonly proceed to a great degree, for the reasons that we have reached here the compara-

tively stable types of organic substances which are not much subject to reduction by the bacterial oxidizing agents. In the case of the free ammonia, however, as this substance does undergo change, we find a progressive improvement or disappearance by oxidation to the mouth of the river, the figure for free ammonia at Grafton being .07 parts per million.

"In considering the indications given by the figures for the oxygen consumption we have a similar condition. Below Pekin there is a general, gradual decrease until Grafton is reached, where the figures for the oxygen consumption again have sunk to a point corresponding to those given by the waters of the tributaries entering the Illinois; and by the waters of this type in general which flow through soil containing a large amount of organic matter. These figures for oxygen consumption have reached a point which is not passed in the waters of this region when exposed to the contamination of ordinary organic substances of vegetable origin.

"In drawing full comparisons in this table, it is necessary to make, to begin with, a calculation of the combined flow through the main Drainage Canal and the Illinois and Michigan Canal. Inasmuch as the water reaches the Desplaines River at Joliet through two canals, carrying unequal portions and drawing different kinds of water, it is necessary to make a calculation of this kind in order to have a starting point for the comparison. The calculation which I refer to is to determine what the constituents present would amount to on the supposition that all the water was carried through one channel instead of two, because in considering the points further down the stream we are dealing with only one channel. In order to make a computation of this kind, I have taken from the published tables of the Chief Engineer of the Sanitary District the flows through the two canals at the periods in question, and have combined them in such a way as to obtain the total flow. Knowing the total flow in each canal and the chemical composition of the water in each canal it is a matter of arithmetical calculation to find what the content would be on the supposition that

all of the water passed through one channel. During the period in question, as deduced from the tables of the Chief Engineer of the Sanitary District, about sixteen per cent. of the flow was through the old, or Illinois and Michigan Canal, and about eighty-four per cent. of the flow through the main Drainage Canal, and these figures were used in a calculation which I will next present, which, however, has not been carried out for all constituents but only for the most important ones.

"Assuming that all of the water passed through one channel, the volume being equivalent to the volume flowing through the two channels, the constituents in that one channel would be this:

	Parts Per Million.
Chlorine	23.5
Free ammonia	3.9
Albuminoid ammonia	1.13
Oxygen consumption in unfiltered water	7.46

"These numbers may be taken as representing then the composition of the total flow through the combined channels. It will be seen by comparing these numbers which I have just given, with those given for the water at Joliet, that there is a discrepancy in some of the figures. That discrepancy depends on this fact, that at Joliet in the basin there is not, or was not at all times, a perfect mixture of the Desplaines and main Drainage Canal water, and the old canal water, so that the results are somewhat dependent on the point there at which the samples were taken, and at the times there at which the samples were taken. Because of that discrepancy the Joliet collection is not considered in the comparison that I wish to make. With this calculated composition of the canal on the assumption that the water all flows through the one channel, I have made some graphic charts which illustrate the variations in the amount of substances present, expressed in parts per million in the whole flow between Bridgeport and Grafton at the mouth of the river, these charts illustrating somewhat more clearly and plainly the variation than do the figures as read

from the tables. The first chart shows a decrease in the chlorine, which is a measure approximately, of dilution by tributary waters." (4212.)

"Q. Professor, state your general conclusions from the work of the summer of 1900, as shown by the tables and charts offered in evidence, as to the character of the waters of the Illinois River and its tributaries.

"A. A consideration of all the tables presented, and of the charts drawn from them leads to this important and necessary conclusion: That in the flow of the sewage water from the pumps at Bridgeport through the Drainage Canal and subsequently into and through the river there is a very remarkable reduction or destruction of organic matter to Peoria; a great increase again between Peoria and Pekin, beyond which the reduction follows which continues to the mouth of the river, and at the mouth of the Illinois River, as far as the organic content is concerned, the Illinois River is not more contaminated than are the ordinary tributaries, and the rivers of this region flowing through a soil which contains large organic matter, and finally, and the most important conclusion to be drawn from these tables and charts, is that the main factor in contamination of the Illinois River is the addition of sewage, stock yards and distillery wastes, of the City of Peoria." (4225-6.)

From the foregoing testimony, based upon the chemical results and conclusions of Professors Jordan, Palmer and Long, and the bacterial results and conclusions of Professors Jordan, Burrill and Gehrmann for the period of 1899 before the opening of the Drainage Canal, compared with the period of 1900, since its opening,—it is demonstrated conclusively that the Illinois River in its flow from Chicago to Averyville purifies itself of the sewage which was emptied into it in 1900 by the Illinois and Michigan Canal and in 1900 by the Chicago Drainage Canal; and also, after it had received the enormous pollution from the cities of Peoria and Pekin, it again in its flow to Grafton purifies itself of the sewage and pollution which it took on at those places.

In addition to the foregoing testimony, as bearing upon the question of the ability of the Illinois River to purify itself of Chicago sewage, Professor Robert F. Zeit made a bacterial examination of the same samples of water which were employed by Professor Long in his examination in 1900, for the purpose of determining the presence of pathogenic bacteria, or the absence of pathogenic bacteria, in the samples of water submitted from the different stations where samples were collected.

He made a number of animal experiments with all those samples given him by Professor Long. The experiments included intra-peritoneal injections of guinea pigs with four cubic centimeters of water of every station. Another set of experiments with the same waters included inoculation, also intra-peritoneally, with culture made by adding one cubic centimeter of suspended water to five cubic centimeters of nutrient bouillon and keeping the mixture in the incubator at a temperature of thirty-seven degrees centigrade for twenty-four hours. Of these cultures, one cubic centimeter was injected intra-peritoneally into guinea pigs. The object of the latter experiments was to favor the growth of pathogenic bacteria and keep back the growth of non-pathogenic saprophytes and water bacteria. In other words, to enrich the water in disease-producing bacteria by adding a favorable culture medium and exposing them to a favorable temperature. Disease-producing bacteria are favored and multiply rapidly at thirty-seven degrees centigrade whereas water bacteria would be somewhat held back by such a temperature. The culture thus enriched in pathogenic bacteria was injected intra-peritoneally and when the animal died cultures were taken from the blood, the heart blood, the spleen and lymph glands. Also smears were made at that time and a diagnosis as to the disease and the organisms causing the death was attempted and made in most of the cases. (4403.)

A brief abstract of Professor Zeit's testimony will indicate the method pursued by him in making these determinations.

Stations Where Water Was Examined.

Lake Michigan, Seven Specimens.

"Guinea pigs infected with four cubic centimeters of the different specimens of water, all recovered. Three of the specimens containing pathogenic bacteria were placed in the incubator. * * * Three guinea pigs were injected, only one died of sepsis. The blood of the animal contained bacilli coli communis. Subcutaneous injections caused only a local abscess. The animal recovered. (4404.)

Western Avenue, in the New Drainage Canal.

"Thirteen specimens were examined. Four different kinds of pathogenic bacteria were found.

"Intra-peritoneal injections of guinea pigs with four cubic centimeters of the sample of water did not prove fatal. Twenty-four hour mixtures grown at thirty-seven degrees centigrade with one part of water and five parts of nutrient bouillon caused a fatal septicemia by intra-peritoneal injection of one cubic centimeter. Several of the pure cultures of the bacilli coli communis obtained from these samples were non-virulent whereas the above mixture invariably proved fatal. (4406.)

Bridgeport.

"Seven samples of water were analyzed. Pathogenic bacteria of five varieties found. The intra-peritoneal injections of four cubic centimeters of several samples of water into a guinea pig did not produce death, whereas one cubic centimeter of a mixture of one part of water to five parts of bouillon kept in the incubator over night at 37 degrees centigrade proved invariably fatal to guinea pigs in a short time. Even subcutaneous injections of one guinea pig produced a fatal septicemia. (4407.)

Lockport.

"Seven samples were analyzed; pathogenic bacteria of five varieties were found. Intra-peritoneal injections of four cubic centimeters into guinea pigs produced no effect.

"Culture of bacteria was uncertain in its effect. Some animals recovered after two cubic centimeters of intra-peritoneal injections. One promptly died of sepsis. All those recovering had an elevated temperature and lost rapidly in weight for several days. One died two weeks later, after having apparently recovered. No cause for death could be made out on post-mortem, and no bacteria were found in the blood or the organs, nor in the abdominal cavity. In the animal which died promptly the proteus forms were most prominent." (4408.)

Joliet.

"Six samples were examined and three varieties of pathogenic germs found. Intra-peritoneal injections of four cubic centimeters into guinea pigs produced no effect. Of four guinea pigs inoculated with one part of different waters and five parts of the bouillon, one died of sepsis, the others recovered." (4409.)

Wilmington, on the Kankakee River.

"Two samples were examined; no pathogenic bacteria found. Intra-peritoneal injections of guinea pigs of four cubic centimeters of water, as well as both the bouillon cultures, proved non-pathogenic.

Morris, Illinois.

"Ten specimens of water were examined and four varieties of pathogenic bacteria were found. Direct intra-peritoneal injections of one specimen of this water caused the death of a guinea pig in eleven days. Other samples of water from the same place did not cause death by direct injection. Experiments with mixed cultures gave uncertain results, the animals sometimes dying and sometimes not." (4411.)

Ottawa.

"Five specimens were examined; pathogenic bacteria found with two. Both the water and the mixed cultures proved non-virulent after intra-peritoneal injections into guinea pigs in the same manner.

Fox River, at Ottawa.

"Four samples were examined and the coli was found. Neither the water nor the mixed cultures proved pathogenic to animals.

La Salle.

"Six samples were received; pathogenic bacteria found, three kinds. One guinea pig, which received an intra-peritoneal injection of four cubic centimeters of this water died of sepsis. The other recovered, but the one-to-five bouillon mixture grown in the incubator for twenty-four hours proved very virulent to the guinea pigs. (4413.)

Henry.

"Five samples were analyzed and four kinds of pathogenic bacteria were found. Direct injection of the water did not cause death. Mixed bouillon cultures were virulent.

Upper Peoria.

"Five samples were analyzed. Coli bacilli found. * * *

"Direct intra-peritoneal injection of water as well as mixed twenty-four hour bouillon cultures proved entirely non-virulent. Even large doses of a twenty-four hour culture at thirty-seven degrees centigrade of one part of water and five parts of bouillon could be given to guinea pigs by intra-peritoneal injection without causing death." (4414.)

"Q. State what evidences of bacteriological purification are indicated by these examinations at this place, and the preceding examinations about which you have testified.

"A. I found that there was a gradual decrease in the num-

ber as well as in the kind of pathogenic or disease producing germs in the water specimens submitted as we got further away from Chicago. Further, I have found that bacteria that are generally known as sewage bacteria or saprophytic organisms gradually decrease as we approach upper Peoria. The number, as well as the kind of disease producing bacteria, as well as the sewage bacteria, is continually decreasing to this point, and the absence of pathogenic effect in animals, I think, is also a sufficient proof that the zone of bacterial self-purification which every river has which has become polluted, must be located somewhere above or near upper Peoria." (4416.)

Professor Zeit made a similar investigation of the water from Peoria to Grafton to that detailed heretofore, all of which is set out in his evidence, and at the conclusion of which he was asked these questions:

"Q. In your testimony today in reference to your examination of the waters of the Illinois River, you stated that the bacterial self-purification of the Illinois River began at Morris, and was practically completed between Henry and upper Peoria? (4448.)

"A. Yes, sir.

"Q. Now, state whether the results of the examinations to which you have just testified strengthen or weaken those conclusions in regard to the water at Grafton?

"A. Bacteriologically, I do not see any reason for changing the opinion expressed, that bacterial purification has taken place in the Illinois River long before the water reaches Grafton."

And again:

"Q. Returning then to your conclusion in reference to the zone of bacterial purification having been reached at Peoria, state whether the conditions which you took into consideration upon which you reach this conclusion are materially different from those existing elsewhere where a similar conclusion has been reached as to other rivers?

"A. I think the zone of purification here ought to be even

nearer to the City of Chicago than what I have allowed. In fact I think that the zone of purification is above upper Peoria. I spoke of it simply there as being bacteriologically complete. I believe that the real zone of bacterial purification is complete very soon after leaving the Drainage Canal." (p. 4469.)

Professor E. G. Smith, of Beloit College, Wisconsin, after a thorough examination of the tables of analyses, as the same appear in "Streams Examination," which were offered in evidence in this case, states: (6760.)

"In my opinion, it seems to me quite clear that there is no pollution dangerous to the public health from the Drainage Canal which receives the outfall from the sewers of Chicago, which reaches down the Illinois River as far as Grafton.

"Q. What evidence have you that will justify the conclusion just expressed?

"A. There are several factors in connection with the river, and the study of the agencies at work in the self-purification of the stream in my opinion would justify that statement. We have the agencies of dilution of the sewage, whereby the sedimentation of the river is augmented, for the reasons previously outlined." * * *

"We have, further, the study of the river, from a chemical standpoint, which shows the purification of the river from that standpoint, and we have also the data from the bacteriological investigations, all a matter of evidence, which show that the waters have purified themselves, from the bacterial standpoint; that is, the waters of the Illinois River at Grafton appear, from a chemical and bacteriological standpoint, as evidenced by these data, to be of the quality of other rivers of this section.

"To sum up these conclusions, in my opinion the several agencies at work make the Illinois River at Grafton about the normal river water in this section." (6760.)

And again he testifies:

"Q. From the tables of analyses submitted in evidence in this case by the witnesses for the defense, and which are published in "Streams Examination," which you have examined,

at what points in the Illinois River does the nitrifying and purifying processes of the sewage coming from Chicago reach towards practical completion?

"A. In studying the tables it is my opinion that the waters of the Illinois River begin to show a very decided purification at Ottawa, which increases and reaches its maximum at Averyville, which is above the City of Peoria. It receives at Peoria and at Pekin a considerable addition of sewage material. Another area or zone of purification commences at that point some distance, thirty miles or so, below, and is practically completed at Grafton, the river at that point appearing to be water of the quality of rivers of this section." (6772.)

And again he testifies as follows:

"Q. Professor, will you please explain the table that you have just read into evidence and its significance, viewed from the standpoint of a sanitarian? (6799.)

"A. This table was prepared to throw some light upon the condition of the Illinois River in its upper reaches, and also such chemical changes as the river underwent as it passed down at the various points indicated in the first column of the same.

"It was also designed to bring out a comparison between the waters of the Illinois River as delivered at the mouth of the Illinois into the Mississippi at Grafton with the quality of the waters of the Mississippi at Grafton, and at two other points down the stream. It was prepared to show what changes the stream underwent, the same being extended over considerable reaches of the river. The data here introduced are taken from the report on "Streams Examination" and from Professor Long's report in the Illinois State Board of Health for 1901, and are those which we take in special consideration in determining the sanitary character of the water and the changes it undergoes from a chemical standpoint.

"One of the most important data is the consideration of the presence of nitrogen, and its various stages of oxidation. Sewagic matters are rich in nitrogen and it becomes therefore

of the utmost importance to determine not alone the presence of the nitrogen, but also any changes the same may have possibly undergone. Nitrogen may be present in nitrogenous organic bodies and in the process of slow decomposition in contact with air the nitrogenous bodies will break down into ammonia, which may subsequently become oxidized into the condition of nitrous acid and later into the condition of nitric acid. Free nitrous acid may be present in the water, but more probably as nitrites. The nitric acid is present in the waters as the dissolved salts, the so-called nitrates. Therefore, nitrous acid is always stated as nitrogen as nitrites and nitric acid as nitrogen as nitrates.

"Chemical analysis, therefore, has to do with the determination of nitrogen present as undecomposed nitrogenous organic compounds. Also with the nitrogen which may have undergone its first stage of decomposition into ammonia, with nitrogen as nitrites and nitrogen as nitrates.

"Referring to these particular tables, I find that Professor Jordan uses an expression, 'Nitrogen as free ammonia.' Professor Palmer, 'Nitrogen as free ammonia.' Professor Long in his tabulations speaks of the ammonia as free ammonia. The tables showing this statement, namely of the ammonia. Professor Long's free ammonia or albuminoid ammonia, could be converted easily into nitrogen as free ammonia by diminishing all of his data upon ammonia or albuminoid ammonia by 3/17ths. The present statement, however, does not affect the interpretation of Professor Long's analysis or the significance to be attached to the same. (6800.)

"The study of nitrogen in these various conditions from albuminoid ammonia to free ammonia, to nitrogen as nitrites, and nitrogen as nitrates, therefore, present the condition of nitrogenous organic bodies in the various stages of decomposition of nitrogenous matters which may have been present. The albuminoid ammonia being an index of the undecomposed or partly decomposed nitrogenous matters, the ammonia where the decomposition has gone to such a point as to eliminate the

nitrogen as nitrites indicating further change of the free ammonia, and the nitrogen as nitrates representing the ultimate stage of the oxidation of the nitrogen.

"The column of total nitrogen which was used only by Professor Palmer, would represent the total nitrogen present in these different states of oxidation.

"By oxygen consumed we understand the power of a water to absorb oxygen from an oxidizing material. This test for the presence of organic matters in water has been used for many years, and, in fact, was used before the introduction of the so-called albuminoid ammonia process. Historically the amount of oxidizable matter in the water was taken as an indication of the general purity or impurity and its suitability for public drinking and domestic purposes.

"At the present time, however, it does not form the only index of the purity or impurity of the water and the sanitary character of the same, but it is one of the indices we use in valuing the quality of a supply.

"The significance of the oxygen consumed lies in the fact that it represents the amount of the oxygen which would be taken up from oxidizing agents by materials dissolved in the water. These may be made up of other material capable of oxidization, but inasmuch as the organic matters in our western streams form practically the whole of such oxidizable matters the oxygen consumed is an index of organic and not inorganic pollution.

"In waters from some other sources the oxygen absorbed by the water may point to inorganic contamination, as, for example, in waters from artesian wells which carry a considerable amount of sulphuretted hydrogen or of metals in lower state of oxidation, such waters wi'l absorb oxygen from oxidizing agents, but this is not true of waters exposed to the air, as in the case of our open streams.

"It is a general and important fact to bear in mind that waters may have a high oxygen consumption and yet reveal a relatively low content of nitrogen in its various stages of de-

composition. This is true, in a general way, of waters coming from our northern country, which require a large amount of potassium permanganate, the agent usually employed in carrying out this test; but strictly sewagic waters carrying a high nitrogen content may also require a large amount of oxygen to oxidize and destroy the organic matters.

"Chlorine is taken also from these tables as an important index of the condition of a stream. Chlorine represents, generally, in our streams, common salt, not harmful in and of itself, but very important in studies of this kind, as salt is the constant friend of and accompanies sewage. The chlorine determinations, therefore, are of importance in estimating the sanitary character of a stream.

"With this explanation of the terms employed in the original determination and their significance, it is of value to note in this table of results which we have, showing the averages of analyses taken from the Desplaines at Joliet, from the Illinois River at La Salle, Averyville, Wesley, Beardstown and at Grafton, from the Missouri River at West Alton, from the Mississippi at Grafton, from the Mississippi at Alton, 100 feet from shore, and from the intake at St. Louis, a very high pollution from sewagic matters in the waters of the Desplaines at Joliet, the same gradually diminishing as we pass down the river as far as Averyville, showing an increased pollution at Wesley, and again diminishing gradually until Grafton is reached, at the mouth of the Illinois River.

"While the data as given by the different men for the periods indicated, namely, Palmer for June, July, August and September, for the years 1899 and 1900, and Jordan for the months of May and June, 1899 and 1900, and Long during the summer months of 1899 and 1900, are not strictly comparable, yet in no essential point do they differ, the conclusions which can be drawn from any one of these observers, pointing clearly to the chemical purification of the waters of the Illinois River by the time they have reached Grafton, as indicated by a diminution in the amounts of free ammonia, in the amounts of

albuminoid ammonia, the notable increase in nitrates, the diminution in oxygen consumed and in the diminution in the amounts of chlorine.

"Another important fact is that the results of 1900 as compared with those of 1899 show at Grafton a diminution in the amounts of free ammonia, a diminution in the amounts of albuminoid ammonia, a diminution in the amount of nitrogen as nitrites, but an increase in the amount of nitrogen as nitrates, a diminution in the amount of oxygen consumed, and the chlorine showing an increase by Jordan, a decrease by Long, and a very slight increase by Palmer.

"*In a word, the important fact brought out is that the waters have undergone a practical degree of purification when they reach Grafton, and the analytical data clearly show that the water in* 1900 *was of a quality superior to that in* 1899 *for these dates given.*

"Applying the same principle to the averages of the results of waters taken from the Mississippi River at Grafton, it is my opinion that the waters of the Illinois River at Grafton, as they empty into the Mississippi River, are better than the waters of the Mississippi River taken from the river at a point above Grafton.

"Applying the same principles of interpretation of the analyses, it is my opinion that the waters of the Illinois, as delivered into the Mississippi River at Grafton, are of a quality, upon these dates for which these averages are given, and they were the only dates from which data were available, which covered similar periods and similar seasonable fluctuations of the stream, and comparing these data the water of the Illinois as delivered into the Mississippi at Grafton, are upon the whole a better water, chemically, for drinking and domestic purposes than the samples taken from the intake at St. Louis, being the waters of the Mississippi River after it has received the flow from the Illinois and the Missouri rivers." (6799 to 6803.)

Professor Leonard P. Kinnicutt, of the chemical department of the Worcester Polytechnic Institute at Worcester, Mass.,

after a thorough study of the tables of analytical data, as the same appears in "Streams Examinations," prepared a series of tables, based upon Professor Jordan and Professor Long's analyses of the waters of the Drainage Canal, and also tables based upon Professor Jordan, Long and Palmer's analyses, which tables appear in the printed record at pages 7343 to 7348.

In testifying to conclusions based upon these tables, Professor Kinnicutt says:

"From the analysis that I have made showing the character of the water at Lockport and the character of the water in the canal at Kedzie avenue, these results indicate very strongly that the septic action has taken place during the passage of water containing sewage through this canal, as shown by the increase in free ammonia, the decrease in albuminoid ammonia, soluble albuminoid ammonia, also in the decrease in oxygen consumed, soluble and suspended; that the results agree in their general characteristics with results that have been obtained by the examination of crude sewage and the effluent from the septic tank in the various places that I have given in table E. The changes are exactly the same in character, the difference only being in amount.

"Q. What effect does this septic action, as you have described it, have upon the sewage of Chicago as it passes through the Drainage Canal?

"A. It has a purifying effect. It also renders the substances which still remain in the sewage more easily acted upon when the sewage enters the river, and it purifies the sewage by removing a part of the solid matter that was in the sewage by throwing it down to the (Vol. 8, pp. 7349) bottom of the canal and by the removal of part of the solid matter by changing it into gas.

"What effect does the septic action which you have described as taking place in the Drainage Canal have upon the bacterial life of the sewage, both the pathogenic and non-pathogenic?

"A. Very little work, as far as I know, has been done re-

garding the action of the septic tank on bacterial life. The best experiments which I know of which are reported are given in the second report of the Royal Commission on Sewage Disposal, 1902, appointed in 1898, which inquired and reported what methods of treating and disposing of sewage may be properly adopted.

"The report of Professor Boyce upon the treatment of Manchester, England, sewage by means of bacterial beds, pages 11 and 12 of the report quoted states: 'Experiments made in Manchester show that B. coli diminishes during the stay in the septic tank, and experiments conducted in the laboratory show that the septic tank liquid is inimical to B. coli, and therefore to other more delicate bacteria.'

"He also gives some experiments made by him, showing that B. coli diminishes in the septic tank.

* * * * * * * * *

"I will say that my opinion is that it diminishes the number of B. coli and the more delicate pathogenic germs and that the total number of bacteria is diminished by ten or fifteen per cent." (Vol. 8, p. 7350.)

Professor Kinnicutt, in studying the problem of purification of the Illinois River, combined the analytical results of Professors Long, Jordan, Palmer, Burrill and Zeit in a number of very interesting tables, and on account of its great importance in shedding light upon the problem involved upon the question of the purification of the Illinois River, we set out part of his testimony in detail.

"Q. Have you studied the chemical data prepared by Professor Long and published in the Board of Health reports of the State of Illinois, which have been introduced in evidence in this case, and the chemical and bacterial data prepared by Professor Jordan, Professor Palmer, Professor Burrill and Professor Zeit?

"A. I have.

"Q. Have you examined the tables prepared by Professor Long and published in the Board of Health reports of the State

of Illinois, which have been introduced in evidence in this case?

"A. I made a careful exmination of the tables of Professor Long as given in the Illinois State Board of Health reports in 1901, and introduced in this case.

"Q. Will you state what conclusions you draw as a chemist and sanitarian from the analytical data presented in such tables by Professor Long?

"A. I have taken the analytical data as given by Professor Long in the Illinois State Board of Health, 1901, which are the results of his examinations of the water at the various stations from Chicago to Grafton on the Illinois River, both for 1899 and 1900. The results of his analysis from June to December, 1899, with the conclusions drawn from those results, are as follows (7354):

"Table 1. Analyses of Lake Michigan tap water, July 17-November 27th, 1899. The total solids are 144, suspended 2, and soluble 142 per million. The free ammonia is 0.05, the albuminoid ammonia 0.103, and it contains no nitrogen as nitrites or nitrates; total oxygen consumed, 1.05; chlorine, 1.77. Two analyses in July, one in August and two in November.

"Table 2. Bridgeport. Pumping station, July 1st to November 27th, 1899, weekly examinations. The results are such as would be obtained from dilute sewage. Total solids, 536.5; soluble solids, 473; (Vol. 8, p. 7355) suspended solids, 63.5; free ammonia, 19.84; albuminoid ammonia, 3.32; nitrogen as nitrites, 0.03; nitrates, 0.0; oxygen consumed, 26.65; chlorine, 95.47.

"Table 3. Lockport Canal, July 3rd-November 29th. The results obtained at this point are very similar to the results obtained at Bridgeport during the same period, and show that during its passage through the canal little change has taken place in the sewage.

"Total solids, 558; soluble, 491; suspended, 67; free ammonia, 19.85; albuminoid ammonia, 3.37; nitrogen as nitrites, 0.03; nitrates, 0.03; oxygen consumed, 27.90; chlorine, 96.97.

"Table 5. Joliet. Illinois and Michigan Canal, July 3rd-November 6th. Total solids, 591; soluble solids, 487; sus-

pended solids, 104; free ammonia, 16.05; albuminoid ammonia, 2.88; nitrogen as nitrites, 0.015; as nitrates, 0.014; oxygen consumed, 25.69; chlorine, 85.49.

"The distance of Joliet from Lockport is only four miles, and the results show that but little change has taken place in the sewage in its flow from Lockport to Joliet. The chief difference in results at this point from those obtained at Lockport being due in my opinion to dilution by water of the Desplaines River, which at this point is mixed with waters from the canal.

"Table 7. Morris. Illinois River, July 5th-November 28th. Total solids, 445; soluble solids, 420; suspended solids, 25; free ammonia, 10.99; albuminoid ammonia, 1.20; nitrogen as nitrites, 0.18; nitrogen as nitrates, 0.07; oxygen consumed, 9.16; chlorine, 61.8. Morris is about 24 miles from Joliet. The Kankakee River enters the Desplaines River about nine miles above Morris, and its diluting effect is shown by the reduction of chlorine from 85.49 to 61.8. (7355.)

"The water of the Kankakee River is a much purer water than that of the Desplaines River at the point of junction, and so the water of the Desplaines is purified to a certain degree by dilution. That the organic matter in the water has began to undergo decomposition is shown by the decrease in free and albuminoid ammonia and increase in nitrogen as nitrites and nitrates. There has also been a decided decomposition of suspended matters, a large part of which was oxygen consuming substances, as the suspended oxygen consumed at Joliet is 10.59, while at Morris it is only 1.09.

"Table 8. Ottawa. Illinois River, July 5th-November 27th. Total solids, 445; soluble solids, 434; suspended solids, 11; free ammonia, 6.23; albuminoid ammonia (Vol. 8, p. 7356), 0.62; nitrogen as nitrites, 0.61; nitrogen as nitrates, 0.74; oxygen consumed, 7.13; chlorine, 57.4. There has been a very decided change in the purity of the water in the river between Morris and Ottawa, a distance of about 24 miles.

"The chlorine shows that there has been very little dilution

of the water of the river between these points, and the very decided decrease in free and albuminoid ammonia with increase of nitrogen as nitrites and nitrates shows that bacterial decomposition of the organic matter is rapidly taking place, changing the organic matter into mineral matter. There has also been a certain amount of deposition of suspended matter.

"Between Morris and Ottawa there is a dam, the Marseilles dam, I believe, but this would have little effect in the character of the water beyond bringing about the removal of suspended matter, there being, according to Professor Palmer's results, dissolved oxygen in the water.

"Table 10. La Salle. Illinois River, July 13th-December 6th. Total solids, 436; soluble solids, 415; suspended solids, 21; free ammonia, 4.66; albuminoid ammonia, 0.58; nitrogen as nitrites, 0.35; nitrogen as nitrates, 1.45; oxygen consumed, 6.99; chlorine, 41.3. (Vol. 8, pp. 7356.)

"These samples were taken about 600 feet above the mouth of the Big Vermillion, and although there has been some dilution as shown by the reduction in chlorine, the very decided decrease in free and albuminoid ammonia with corresponding increase in nitrogen as nitrates, and the decided decrease in oxygen consumed shows that during the stretch of river between Ottawa and La Salle the processes of purification have been very active.

"Table 12. Henry. July 10th-December 4th. Sample taken from above the dam. Total solids, 451; soluble solids, 426; suspended solids, 25; free ammonia, 3.28; albuminoid ammonia, 0.553; nitrogen as nitrites, 0.517; as nitrates, 1.39; total oxygen consumed, 7; chlorine, 43.2.

"The slight increase in chlorine would indicate a slight addition of sewage to the river, probably from La Salle and Peru, total population 20,000. There has, however, been only slight changes between.

"Table 13. Peoria Narrows. July 5th-November 23rd. Total solids, 422; soluble, 398; suspended solids, 24; free ammonia, 0.895; albuminoid, 0.572; nitrogen as nitrites, 0.141;

nitrogen as nitrates, 1.10; oxygen consumed, 6.86; chlorine, 33.04.

"The chlorine shows that there has been more (Vol. 8, p. 7357) or less dilution between Henry and the Narrows, but the great change has been in the removal of free ammonia and nitrogen as nitrites. This shows that the principal change between Henry and the Narrows has been the last process in the changing of the organic matters of sewage into mineral matter.

"Table 14. Wesley City. July 5th-November 29th. Total solids 493, soluble solids 438, suspended solids 55, free ammonia 4.36, albuminoid ammonia 3.20, nitrogen as nitrites 0.026, nitrogen as nitrates 0.106, oxygen consumed 17.44, chlorine, 34.97.

"The increase in all the above constituents, especially the free ammonia, albuminoid ammonia and oxygen consumed, shows that a large amount of organic mater has been added to river between Peoria Narrows and Wesley City, a distance of only about six miles. This addition from my knowledge of the river is from the town of Peoria, 50,000 inhabitants, with its large cattle sheds and distilleries.

"Table 15. Pekin. July 18th-November 30th. Total solids 419, soluble solids 393.0, suspended solids 26, free ammonia 1.39, albuminoid ammonia 0.828, nitrogen as nitrites 0.273, nitrogen as nitrates 0.71, oxygen consumed 7.81, chlorine 34.76.

"The distance to Pekin from Wesley City is about (Vol. 8, Page 7357) ten miles, yet in this stretch a great amount of purification seems to have taken place much more than I should have expected. This is shown by the very great decrease in free and albuminoid ammonia, oxygen consumed, and increase in nitrites and nitrates. There is no marked dilution as shown by the amount of chlorine.

"Table 16. Havana. July 6th-December 14th.

"Total solids, 432; soluble solids, 381; suspended solids, 51; free ammonia, 1.69; albuminoid ammonia, 0.695; nitrogen as nitrites, 0.21; nitrogen as nitrates, 1.02; oxygen consumed, 7.18; chlorine, 29.17.

"The distance from Wesley City to Havana is about 24 miles. Between the two places is a dam known as Copperas Creek dam and a stream known as Mackinaw Creek enters the river. The samples were taken above Spoon River. There appears by the chlorine figure some dilution between Pekin and Havana. There is a slight increase in the free ammonia and in the nitrogen as nitrates, while the nitrogen as nitrites is slightly lower. We see here, as at Peoria Narrows, the final changes of organic matter into mineral matter taking place.

"Table 26. Grafton. July 10th-November 28th.

"Total solids, 362; soluble solids, 306; suspended solids, 56; free ammonia, 0.247; albuminoid ammonia, 0.455; nitrogen as nitrites, 0.044; nitrogen as nitrates, 0.59; oxygen consumed, 5.61; chlorine, 17.5. (Vol. 8, 7358.)

"The distance from Havana to Grafton is 119 miles. There is a dam between Grafton and Havana and the water of the river is diluted by the Spoon and Sangamon rivers, both of which enter the Illinois between Havana and Grafton. The water at Grafton, as shown by the analyses, has been so purified between Havana and Grafton that it now closely resembles the water at Peoria Narrows. It shows only in the chlorine and nitrogen as nitrates evidence of part pollution.

"Table 21. Grafton, on the Mississippi. July 10th-November 20th. Samples taken above the junction with the Illinois.

"Total solids, 278; soluble solids, 169; suspended solids, 109; free ammonia, 0.08; albumnioid ammonia, 0.443; nitrogen as nitrites, 0.001; nitrogen as nitrates, 0.03; oxygen consumed, 8.52; chlorine, 1.77. The river differs greatly from the Illinois in the amount of chlorine it contains, 177 against 17.5, and, while it contains a less amount of solid substances in solution, than the Illinois, it contains a greater amount of suspended matter. The amount of organic nitrogenous matter and carbonaceous matter in the two rivers is about the same, as shown by the albuminoid ammonia and oxygen consumed.

"I have also prepared tables from the results of Professor Long's analyses at the various stations from Chicago to Grafton, from June to October, 1900, and they are as follows:

"Table 41. Chicago City Water. June 5th-September 4th, 1900.

"Total solids, 148; soluble solids, 148; suspended, none; free ammonia, 0.016; albuminoid ammonia, 0.094; nitrogen as nitrites, none; nitrogen as nitrates, trace; oxygen consumed, 2.93; chlorine, 2.17. Four analyses in June, five in July, four in August and one in September. These analyses would indicate that the water was not quite as pure in 1899 as 1900, but are results that would be obtained with a potable water. (7358.)

"Table 43. Western Avenue Bridge, Drainage Canal. June 5th-September 4th.

"Total solids, 203; soluble solids, 178; suspended solids, 25; free ammonia, 1.34; albuminoid ammonia, 0.95; nitrogen as nitrites, 0.11; nitrogen as nitrates, 0.12; oxygen consumed, 6.28; chlorine, 9.2 (7359.)

"If this is compared with the analyses of the water of the Illinois and Michigan Canal in 1899 at Bridgeport, it is seen that it is a very much more dilute sewage, or sewage mixed with a much larger amount of water.

"Table 44. Lockport Canal. June 4th-September 4th.

"Total solids, 212; soluble solids, 193; suspended solids, 19; free ammonia, 2.16; albuminoid ammonia, 0.76; nitrogen as nitrites, 0.06; nitrogen as nitrates, 0.00; oxygen consumed, 5.29; chlorine, 12.6.

"This analysis, when taken in connection with Table 43, as I have already pointed out, shows that the dilute sewage has undergone very decided changes in its passage through the canal.

"Table 45. Joliet, Desplaines River. June 4th-October 1st.

"Total solids, 280; soluble solids, 245; suspended solids, 35; free ammonia, 4.66; albuminoid ammonia, 0.85; nitrogen as nitrites, 0.09; nitrogen as nitrates, 0.02; oxygen consumed, 6.97; chlorine, 31.4.

"This analysis shows that the water is not as pure as it has been up there, but, when compared with the analyses made in 1899, shows that it contains very much less organic matter than it did at that time. (Vol. 8, p. 7359.)

"Table 46. Morris. June 4th-October 3rd.

"Total solids, 251; soluble solids, 222; suspended solids, 29; free ammonia, 2.84; albuminoid ammonia, 0.63; nitrogen as nitrites, 0.27; nitrogen as nitrates, 0.17; oxygen consumed, 6.4; chlorine, 17.8.

"The dilution by the water of the Kankakee is here shown by the chlorine as in 1899. The water is very much purer than in 1899.

"Table 47. Ottawa. June 4th-October 16th.

"Total solids, 266; soluble solids, 238; suspended solids, 28; free ammonia, 0.81; albuminoid ammonia, 0.39; nitrogen as nitrites, 0.37; nitrogen as nitrates, 0.92; oxygen consumed, 5.94; chlorine, 17.2.

"There has been even more marked purification of the water in its run of 24 miles in 1900 than 1899, as shown by the reduction of free albuminoid ammonia, and oxygen consumed, and by increase of nitrites and nitrates.

"That there has been little, if any, dilution is shown by the chlorine. The water is much purer than in 1899.

"Table 49. La Salle. June 4th-October 3rd.

"Total solids, 278; soluble solids, 252; suspended solids, 26 (7360); free ammonia, 0.55; albuminoid ammonia, 0.36; nitrogen as nitrites, 0.25; nitrogen as nitrates, 0.77; oxygen consumed, 5.6; chlorine, 15.8.

"The purification which was noted at Ottawa has continued. The chlorine shows the effect of slight dilution. The river much purer than in 1899.

"Table 51. Henry. June 7th-October 1st.

"Total solids, 283; soluble solids, 248; suspended solids, 35; free ammonia, 0.41; albuminoid ammonia, 0.4; nitrogen as nitrites, 0.22; nitrogen as nitrates, 1.06; oxygen consumed, 5.86; chlorine, 16.9.

"The results similar to those obtained in 1899; the slight increase in chlorine indicates the addition of the sewage of La Salle and Peru. Slight changes as regards organic matter. River purer than in 1899.

"Table 52. Peoria Narrows. June 7th-October 9th.

"Total solids, 265; soluble solids, 244; suspended solids, 21; free ammonia, 0.21; albuminoid ammonia, 0.34; nitrogen as nitrites, 0.12; nitrogen as nitrates, 0.95; oxygen consumed, 5.05; chlorine, 15.5.

"The change, as was the case in 1899, is the decrease in free ammonia, albuminoid and nitrogen as nitrites. Water much purer than in 1899.

"Table 53. Wesley City. May 30th-October 10th.

"Total solids, 333; soluble solids, 262; suspended solids, 71; free ammonia, 1.62; albuminoid ammonia, 1.34; nitrogen as nitrites, 0.11; nitrogen as nitrates, 0.72; oxygen consumed, 9.91; chlorine, 16.6.

"The analyses show the addition of the sewage of Peoria.

"Table 54. Pekin. May 30th-September 12th.

"Total solids, 326; soluble solids, 250; suspended solids, 76; free ammonia, 0.39; albuminoid ammonia, 0.46; nitrogen as nitrites, 0.17; nitrogen as nitrates, 0.74; oxygen consumed, 7.01; chlorine, 15.

"As in 1899, a great amount of purification seems to have taken place between Wesley City and Pekin, a distance of nine miles. River much purer than in 1899.

"Table 55. Havana. June 7th-October 10th.

"Total solids, 322; soluble solids, 245; suspended solids, 77; free ammonia, 0.41; albuminoid ammonia, 0.41; nitrogen as nitrites, 0.18; nitrogen as nitrates, 0.77; oxygen consumed, 6.46; chlorine, 15. (7360-61.)

"We have here in the 24 miles similar results to 1899, and a very slight increase in free ammonia and in nitrates, and a slight decrease in albuminoid ammonia. Mackinaw Creek enters the river above Havana.

"Table 58. Grafton. June 7th-September 24th.

"Total solids, 331; soluble solids, 243; suspended solids, 88; free ammonia, 0.07; albuminoid ammonia, 0.36; nitrogen as nitrites, 0.03; nitrogen as nitrates, 0.87; oxygen consumed, 5.85; chlorine, 10.6.

"The water between Havana and Grafton has been so purified that the nitrates and chlorine are the only indications of the pollution of the river at Peoria.

"Table 59. Grafton, on the Mississippi River. July 31st. September 24th.

"Total solids, 347; soluble solids, 152; suspended solids, 195; free ammonia, 0.07; albuminoid ammonia, 0.54; nitrogen as nitrites, 0.02; nitrogen as nitrates, 0.03; oxygen consumed, 11.73; chlorine, 2.

"The great difference in the Mississippi at Grafton from the Illinois at Grafton in 1900, as in 1899, was in the amount of chlorine, 2 against 10.6, and in the suspended matter. The Mississippi, as (7361) shown by the albuminoid ammonia, and oxygen consumed, contained in 1900 more organic matter than the Illinois in 1900, and figures for oxygen consumed show a greater amount of organic matter, both in solution and suspension.

"The data are, oxygen consumed:

	Total.	Soluble.	Suspended.
Mississippi	11.73	7.08	4.65
Illinois	5.85	4.82	1.03

"Q. Have you prepared any table from the chemical and bacterial analysis of Professors Jordan, Palmer, Burrill and Zeit, as they appear in Streams Examinations, which have been introduced in evidence in this case, and the tables of Professor Long as they appear in the Board of Health report of the State of Illinois, which also have been introduced in evidence in this case?

"A. I have.

"Q. Will you state in a general way the method employed by you in preparing the table which will subsequently be introduced in evidence by you at its proper time from the chemical and bacterial analysis of Professors Jordan, Palmer, Burrill and Zeit? (7362.)

"A. Yes, sir. The general method was to obtain the mean of the average of the analyses made by these various named per-

sons during given periods of examination, as given in "Streams Examination" and the report of the State Board of Health of Illinois for 1901, which tables have already been introduced in evidence, and during times which were comparable with each other.

"Q. In the examination of these tables did you strike an average for similar periods in different years of the analyses whose tables have already been introduced in evidence?

"A. I did.

"Q. And where that method was not pursued your tables show it?

"A. My tables show it.

"Q. Have you prepared a table from the analytical data of Professors Jordan and Palmer from May to January, 1899, and from January to May, 1900?

"A. I have. I have prepared Tables 41 to 52, inclusive, which are the mean of Jordan's and Palmer's results, May to December, inclusive, 1899.

"Q. Will you produce and read the table prepared by you and as above described?

"A. The tables are as follows, numbered 41 to 52, both inclusive." (7362.)

These tables are set out in full in the printed record, at pages 7363 to 7368, and all of these tables are illustrated by charts in Professor Kinnicutt's testimony, and from the charts he draws his conclusions.

"At Joliet the high free ammonia, the high albuminoid ammonia, the high oxygen consumed, the low nitrites and low nitrates show that at this point we have a water very badly polluted by organic matter or sewage. The rapid decrease in the amount of ammonia, free ammonia and albuminoid ammonia, and the oxygen consumed, from Joliet to Morris, and at the same time the increase in nitrogen as nitrites and nitrates shows the amount of purification that has taken place between these places. The most active zone of decomposition seems to be in the neighborhood of Ottawa. This is shown not only by

the falling curves denoting free albuminoid ammonia and oxygen consumed, but by the rising curves denoting nitrogen as nitrites and nitrates, the nitrite curve reaching its maximum at this point. As we proceed down the river from Ottawa to La Salle the curve shows continued purification. The slight fall in the curve from nitrogen (7371) as nitrates being due to the removal of nitrates from the water by green plant life. From La Salle to Henry the curve for the free ammonia and nitrogen as nitrites still descend. The slight rise in the curve for albuminoid ammonia and oxygen consumed indicates a slight addition of organic matter to the water of the river between La Salle and Henry. Below La Salle the purification continues down to Averyville, as shown by the gradual decrease of free and albuminoid ammonia, nitrogen consumed and nitrogen as nitrites.

"At Averyville the chart shows, as was shown by Professor Long's table, the result of the final change of the organic to inorganic matter; low free ammonia; low free albuminoid ammonia; low nitrogen consumed, with high nitrates. The results obtained by Long at Averyville from July 5th to November 25th agree closely with the mean of Jordan's and Palmer's results from May to December, as is shown in the following table:" (7372.)

"From Averyville to Wesley City we notice the effect of the contamination at Peoria by the rise in free ammonia, albuminoid ammonia, oxygen consumed and the decrease in nitrites and nitrates.

"Jordan's and Palmer's results show less effect from this contamination than do Professor Long's analysis. This may be due to the possibility that at the point where Professor Long collected his samples there may not have been complete mixing of the sewage of Peoria with the river water, or that where Palmer and Jordan's samples were taken there was not a complete mixing of the river water with the sewage.

"Between Wesley City and Pekin the purification again begins, and this purification is continued all the way down to

Grafton, where the low albuminoid ammonia, low nitrogen as nitrites, low oxygen consumed, shows the removal of the polluted matters entering the river at Peoria. If we again compare the results of Professor Long with the mean of Professors Jordan and Palmer, we find a close agreement as regards the condition of the water at Grafton." (7373.)

"Q. Will you state what the chart shows?

"A. Chart 2 shows the amount of free ammonia, albuminoid ammonia, nitrogen as nitrites, nitrogen as nitrates, and oxygen consumed, as shown by the mean of the analysis made by Professors Palmer and Jordan of samples taken at Joliet, north of Jackson Street, on the Desplaines River; Morris, Ottawa, La Salle, Henry, Averyville, Wesley City, Pekin, Havana, Beardstown, Grafton, on the Illinois River, from January to June, 1900, as given in Tables 53 to 64, inclusive.

"Q. What sanitary conclusions do you draw from the chart just introduced?

"A. At Joliet the amount of free ammonia, albuminoid ammonia, oxygen consumed, is not half as great as in 1899, showing much less pollution of the water in 1900 than in 1899. There is, as in 1900, a rapid fall in the curves representing the amount of free ammonia, albuminoid ammonia, and oxygen consumed, in the stretch of river between Joliet and Ottawa, with corresponding rise in nitrogen as nitrites and nitrates, *showing that the active zone of decomposition is, as in* 1899, *in the neighborhood of Ottawa.*

"There is a slight increase in the oxygen consumed curve between Ottawa and La Salle. The albuminoid ammonia curve remaining nearly stationary, indicating a (7382) slight addition of organic matter to the water between Ottawa and La Salle. There is then a steady elimination of organic matter from the river down to Averyville, as shown by the gradual decrease of the curves for free ammonia, albuminoid ammonia, nitrogen as nitrites, oxygen consumed, with an increase of nitrogen as nitrates. The curve of free ammonia does not rise between Averyville and Wesley City, but the rise is noticed

between Wesley City and Pekin. This may be due to the fact that the decomposition of the nitrogenous matter did not begin quite as quickly in 1900 as in 1899. The slight delay, a delay represented by about nine miles on the river, being probably caused by the lower temperature of the water in the winter and spring months of 1900; and it is also to be noted that the increase in the albuminoid ammonia curve continues down to Pekin, while in 1899 the decrease began between Wesley City and Pekin. From Pekin to Havana there is a gradual decrease in the organic nitrogenous matter, as shown by the free ammonia and albuminoid ammonia curve. From Havana to Kampsville the free and albuminoid ammonia increased very slightly and then decreased to Grafton. The nitrogenous nitrites and the oxygen consumed also rise slightly from Havana to Beardstown, then decrease between Beardstown and Grafton. (7382.) The nitrogen as nitrites increased continuously from Havana to Grafton. The purification of the river from Havana to Grafton is indicated on the curves by the gradual increasing amount of nitrogen as nitrates. The decrease in free ammonia and albuminoid ammonia not being so evident on account of spring thaws and freshets.

"Q. Taking the two charts which you have introduced in consideration, the first for the months from May to December, inclusive, of '99; the second from January to June, inclusive, 1900, based upon the chemical results of Jordan and Palmer, as hereinbefore named by you, what sanitary conclusions do you draw from the comparison of the results as they appear upon these two charts?

"A. The curves on the chart representing the river from June to January, '99, closely resemble the curves given on the chart representing the river from January to June, 1900, showing that the general character of the purification that took place is the same for the two years, the small differences being chiefly due to the effect of dilution and to seasonable variations that take place in the river. Both charts show by the rapid decrease of free ammonia, albuminoid ammonia and oxygen consumed

and increase of nitrogen as nitrites and nitrates, the purification that takes place between Joliet and Ottawa, in both years, *and that the zone of the most active decomposition of organic matter has not been shoved, or been pushed further down the* (7383) *river by the increasing volume of the river, due to the opening of the Sanitary Canal.* The purification is then shown to continue in both years as the river flows to Averyville, as shown by the decrease in the free ammonia, albuminoid ammonia, oxygen consumed and nitrogen as nitrites. The chart for June to January, '99, shows, by the slight increase in albuminoid ammonia and oxygen consumed between La Salle and Henry, that a certain amount of organic matter enters the river at this point, but the continued decrease of free ammonia and nitrogen as nitrites indicates that it is either not very large in amount, or of a character not easily decomposed. In both periods, between La Salle and Henry, the nitrogen as nitrites shows a slight decrease, the nitrogen as nitrates also decreasing. The decrease of nitrogen as nitrates at this point is probably due to algæ, or green plant life. Between Henry and Averyville, the nitrogen as nitrites still decreasing, the nitrogen as nitrates shows an increase more marked between January and June, 1900, than between June and January, 1899. The reason for less increase in nitrogen as nitrates between Henry and Averyville between June and January than between January and June is due to the larger amount of green plant life living in river waters in the summer and autumn months than in the winter and spring months. The rise in free ammonia, albuminoid ammonia, and oxygen consumed, between Averyville and Wesley City, show the pollution which enters the river between these two points in both years, which is removed in both years, as shown by the decrease in these substances as the river flows downward to Grafton. The river in both years, as shown by the curves, purifies itself again between Wesley City and Grafton, as it did between Joliet and Averyville. The slight rise in free and albuminoid ammonia between Beardstown and Kampsville from January to June, 1900, is probably

due to seasonable variations, as the river and pond waters contain more free albuminoid ammonia in the winter and spring than at any other time. In the lower stretches of the river in 1899 we find by the charts decreasing nitrites and nitrates; in the chart for 1900 we find, however, that, while the nitrites decrease, the nitrates increase. This difference in nitrates in the lower stretches of the river is due to green plant life. This green plant life being more abundant in the summer and autumn months of 1899 than in the winter and spring months of 1900, removed, therefore, the nitrites to a much larger extent in 1899 than in 1900.

"Q. Have you prepared a chart based upon the bacterial tables of Professors Burrill and Jordan for the months of May and December, inclusive, for 1899?

"A. I have. (7384.)

"Q. Will you produce and make a part of your evidence the chart thus prepared?

"A. The chart with the caption 'Mean Results, Illinois River, Bacterial Table, Burrill and Jordan, Months of May to December, Inclusive, 1899, L. P. Kinnicutt,' is as follows:" (7385.)

"Q. Will you state what the chart you have just introduced in evidence shows?

"A. This chart shows the number of bacteria as given by the mean of the analyses of Professors Burrill and Jordan of samples taken at Joliet, north of Jackson Street, on the Desplaines, at Morris, at Ottawa, at La Salle, at Henry, at Averyville, at Wesley City, at Pekin, at Havana, at Beardstown, at Kampsville and at Grafton, on the Illinois River, from January to June, 1899. The abscissæ give the distance in miles of various places from Chicago, the co-ordinates, the number of bacteria in one cubic centimeter of water.

"Q. Will you state what sanitary conclusions you draw from the chart which you have just introduced in evidence?

"A. The study of this chart, in connection with the chart for the chemical data of the same period, show a striking agree-

ment between the chemical and bacterial data. The bacteria, which numbers over 1,000,000 per cc. at Joliet, decrease very rapidly to La Salle. In this distance of about 62 miles the number has fallen from 1,000,000 to 17,412 per cc. *This shows, as did chemical results, that the zone of the greatest purification is near Ottawa.* There is a slight rise in the number of bacteria of only 2,000 per cubic centimeter between La Salle and Henry, a rise coincident with the rise for (7387) albuminoid ammonia in the chemical chart for the same period. From this point the number falls steadily until Averyville is reached, the number there being 4,756 cubic centimeters. Then, on account of the pollution entering the river at Peoria, the number rises immediately to 995,503. This sudden rise in the number of bacteria shows how quickly sewage pollution can be detected by bacterial examination. From this point the number of bacteria rapidly falls, and at Kampsville there are only 7,457 per cubic centimeter, showing the great amount of purification that has taken place between Wesley City and Kampsville. Between Kampsville and Grafton there has been, as was the case between La Salle and Henry, a very slight increase in the number of bacteria, 2,005 per cubic centimeter. This increase is not at all significant, as a slight increase at this point, after the rapid decrease between Wesley City and Kampsville, is absolutely without significance as regards the problem of stream purification.

"Q. Have you prepared a chart based upon the bacterial tables which you have prepared from Burrill and Jordan's tables, and which you have already introduced, for the months of January to June, inclusive, 1900?

"A. I have.

"Q. Will you produce the chart which you have thus prepared, making it a part of this evidence? (7388.)

"A. The chart with the caption 'Mean Results, Illinois River, Bacterial Tables, Burrill and Jordan, Months, January to June, Inclusive, 1900, L. P. Kinnicutt,' is as follows:" (7388.)

"Q. Will you state what this chart shows?

"A. This chart shows the number of bacteria as given by the mean of analyses of Professors Burrill and Jordan, of samples taken at Joliet, north of Jackson Street, on the Desplaines River, at Morris, at Ottawa, at La Salle, at Henry, at Averyville, at Wesley City, at Pekin, at Havana, at Beardstown, at Kampsville and at Grafton, on the Illinois River, from January to June, 1900, the data being given in Tables 53 to 64, inclusive. The abscissæ give the distance in miles of the various places from Chicago, the co-ordinates the number of bacteria in one cubic centimeter of water.

"Q. What conclusions do you draw from this chart?

"A. This chart shows the amount of bacteria at Joliet to be about 900,000 per cubic centimeter, falling to 110,000 at Ottawa, *showing that the greatest amount of purification took place, exactly as it did in '99, in the neighborhood of Ottawa.* Between Ottawa and La Salle there is a slight increase in bacteria, corresponding to the slight increase in the oxygen consumed, as shown in the chart representing the chemical data for this same period. From Ottawa to Averyville the number of bacteria rapidly decreases until at Averyville one cubic centimeter contains about 45,000 bacteria. At Wesley City there is an increase in bacteria amounting to 60,000, and which (7390) continues to increase until Pekin is reached. This increase, due to pollution, was shown in the curve for albuminoid ammonia in the chart representing the chemical curves for the same period. The rapid purification in the spring months does not begin until after the river passes Pekin. From Pekin to Havana the curve falls rapidly, showing that great purification has taken place. From Havana to Beardstown there is an increase in bacteria, followed by a quick decrease, the number at Kampsville being only about 40,000. From Kampsville to Grafton there was, in 1899, a slight increase in the number of bacteria, but the number at Grafton is less than at Averyville, showing the removal of the polluting material entering the river at Peoria. As was to be expected, the number of bacteria in the lower stretches of the river, as shown by this curve, is greater

during the summer and autumn months of 1899 than in the spring months of 1900. The soil bacteria washed into a stream during the later winter and early spring months always increases largely the number of bacteria in a river during that period." (7391.)

"Q. Will you explain the construction of these two charts just introduced, and what they show?

"A. The first chart gives the curve representing the amount of the total solids, suspended solids, soluble solids; the total oxygen consumed; the soluble oxygen consumed for the months of May, June, July and August of 1899 and 1900, from the mean of the results obtained by Professors Jordan, Long and Palmer, for the months in the two stated years, the solid line representing the year 1899, the broken line the year 1900. The abscissae gives the distance of the various stations from Chicago at which the analyses were made. The co-ordinates give the parts per million of the various substances.

"The second chart is similar to the first one, except that the curves there given represent the amount of chlorine, free ammonia, albuminoid ammonia, nitrogen as nitrites, nitrogen as nitrates, obtained in the same manner as the curves in the first chart.

"Q. Taking the two charts together, what sanitary conclusion do you draw from them?

"A. The resemblance of the various curves for 1899 and 1900 show that the general process of purification took place in the same way after the opening of the canal as before it was opened. It is also to be noted that with the exception of the (Vol. 8, p. 7427) curves representing suspended solid matter, suspended oxygen consumed and nitrogen as nitrates, that the curves for 1900 are below the curves for 1899, showing that in 1900 a given volume of the river contains less organic impurities than in 1899.

"To go more into detail in regard to these data, it is seen that the curves for the total soluble and suspended matter fall between Joliet and Morris, and that this fall is more marked

in 1899 than in 1900, on account of the large amount of solid matter contained in the river in the former year. Between Morris and Ottawa there is very little change as regards the solid substances in the river. Also between Ottawa and La Salle the curves for total solids and soluble solids show that there is a comparatively little change in the amount of these substances between these two places. The curve for 1899 for suspended solids rises between Ottawa and Henry and the curve for 1900 for suspended solids rises between La Salle and Henry, both curves falling again between Henry and Averyville. Between Averyville and Wesley City the curves in both years show an increase in the solid matter in the river. It is shown from the curve representing albuminoid ammonia to be of an animal and vegetable character.

"From Pekin to Grafton the curves show very little increase or decrease in total substances in the river, but the (7427) curves for solid substances, while showing little change for 1900, shows a slight decrease in 1899. In both years the curves show an increase in the suspended matter in the lower stages of the river, but that this matter is mineral rather than organic is shown by the curve representing oxygen consumed, which runs almost a straight line from Havana to Grafton. The curve representing oxygen consumed shows a large amount of organic matter at Joliet which they show is removed to great extent in both years before the river reaches Morris.

"Between Averyville and Pekin the rapid rise in these curves shows an increase in organic matter between these points, and the decrease in the curves between Pekin and Grafton shows a removal of organic matter taking place in exactly the same way in both years.

"The curves representing the free and albuminoid ammonia show a very large amount of organic matter in both years at Joliet, a sharp decrease to Ottawa, and then a gradual decrease to Averyville.

"The curves, especially the curve representing the albuminoid ammonia, rises slightly between Averyville and Pekin.

showing the effect of a pollution at Peoria, and then both gradually falling until Grafton is reached, where the minimum amount of both free and albuminoid ammonia is shown by the curves to be present. (7428.)

"*The nitrogen curves, especially the nitrogen as nitrites, show that the zone of the greatest decomposition in the upper stages of the river, in both years, is in the neighborhood of Ottawa, and that the added volume due to the opening of the Sanitary Canal has not pushed this zone of decomposition further down the river.* Beyond Averyville the rapid rise in the curve for free albuminoid ammonia, nitrogen as nitrites, and the decrease in the curve for nitrates, show the addition of polluted waters in both years at Peoria. This, as shown by the curves, is more marked in 1899 than in 1900. The effect of this pollution is shown by the curves to extend to some degree to Havana, but at Grafton, the only curve to show that the water has been polluted at Peoria, is the nitrogen as nitrates.

"The curves also show that a given volume of the river water contained less organic nitrogenous matter in 1900 than in 1899.

"The chlorine curve gives an idea of the amount of dilution that took place in the flow of the river from Joliet to Grafton." (7429.)

"Q. Will you state what the chart just introduced in evidence shows?

"A. The chart shows the bacterial contents of the river between Joliet and Grafton as obtained from results of Burrill, Jordan and Zeit, for the months of May, June, July and August, 1899 and 1900. The light lines between Havana and Grafton represent only the months of May and June, being the mean of Burrill and Jordan's results for May and June, Zeit making no determinations at these points. Consequently it is impossible to obtain a curve at these points representing the four months.

"Q. Will you state what sanitary conclusions you draw from the chart just introduced in evidence?

"A. Both curves show a great number of bacteria per cc. at Joliet. They then show a great decrease between Joliet and La Salle, a distance of 65 miles. The curves for 1899 show that between La Salle and Henry the number of bacteria increases rapidly, owing principally to the sewage of La Salle and Peru, but decrease almost as rapidly between Henry and Averyville.

"The curve for 1900 shows also a slight increase from bacteria between La Salle and Henry and also a further increase between Henry and Averyville, due probably to some local cause. Between Averyville and Wesley City the two show an increase of bacteria in both years (7431), greater, however, between Wesley City and Pekin, in 1899 than in 1900. In both years the curves show a very great decrease between Wesley City and Havana, a distance of 40 miles, and the decrease continued, though not so rapidly, between Havana and Beardstown.

"The curve for 1900 shows this decrease continues to Kampsville, while the curve for 1900 shows a rise between Beardstown and Kampsville. In both years they show an increased number between Kampsville and Grafton. The curve shows only three places in the river where the bacteria was greater in 1900 than in 1899, namely, Averyville, Havana and Beardstown. The number of bacteria at Grafton is shown to be about 6,000 less per cc. in 1900 than in 1899." (7431.)

"Q. Professor, in preparing these charts and tables, why did you take the mean?

"A. The reason that I took the mean was because it is my opinion that in taking a mean of the analytical data obtained by the various observers at the various stations on the Illinois River more accurate information can be obtained of the changes that take place in the river than by studying the data of any one person.

"Further, I did this because it is a method commonly employed in all scientific investigations, as, for instance, what are now considered as the figures representing the correct

amount of hydrogen and oxygen in water were obtained, not from the results of a single observer, but by combining the data of many different experiments made by many different observers." (7445-7446.)

"Q. Professor, will you state the steps of purification of Chicago sewage as the same passes out of the sewers of Chicago into the Chicago River, thence into the Drainage Canal, and from thence to the Desplaines and Illinois rivers, as you have shown by the tables and charts which you have offered in evidence in this case?

"A. The sewage of Chicago as it enters from the sewers into the Drainage Canal undoubtedly contains a small amount of oxygen, and the first action that takes place is undoubtedly anaerobic action, in which part of such substances like urea are decomposed, ammonia being given off. The action in the sanitary canal is an anaerobic action, or very similar to that which takes place in the septic tank. By this action about 20 per cent. of the organic matter, as measured both by the loss in the albuminoid ammonia and by the loss in oxygen consumed, is removed from the sewage. Also a certain amount of suspended matter is removed and a certain amount of suspended matter has been rendered soluble and a certain amount has been converted into gases and into simpler products.

"By this action the sewage is not only purified, but changed so that further purification will take place more easily. The next stage in the purification is the aerobic stage. Undoubtedly in the upper stretches of the river near Joliet we have both aerobic and anaerobic action taking place. Further down (7447), as at Ottawa, we have principally aerobic or nitrifying action. At about this point, both in 1899 and 1900, is the zone of greatest decomposition. From this point the action, in my opinion, is entirely aerobic or nitrifying action, continued purification going on until we come to Averyville.

"Between Averyville and Wesley City the tables and diagrams that I have made show that a large amount of organic polluted matter is added to the river. At Pekin, or between

Peoria and Pekin, we have also again more or less anaerobic action with aerobic action taking place.

"The purification continues, and between Pekin and Havana the action that takes place is aerobic or a nitrifying action. The aerobic purification then goes on until at Grafton all the original organic matter which was in the sewage at Pekin has been decomposed and changed.

"Q. From a careful consideration of all the tables and charts introduced into evidence by you, and consideration of it as a whole, what conclusions do you draw as to the effects of emptying the sewage of Chicago into the Drainage Canal and from thence into the Desplaines River and Illinois River, as to the effects of said sewage upon the waters of the Illinois River?

"A. The effect of emptying the sewage of Chicago into the Drainage Canal into the Desplaines River at Joliet and then into the Illinois River is to increase the amount of organic (7447)matter in the upper stretches of the river.

"The effect, however, of adding this organic matter to the upper stretches of the river is not noticed at Averyville, except in the increased nitrogen contents of the river and the high chlorine, and the same can be said at Grafton, at the mouth of the Illinois River. At that point the effect of the addition of the sewage to the Illinois River is seen only in the high chlorine and the nitrogen as nitrates. This nitrogen content of the river is very different from the nitrogen content of the river at or above Ottawa. It is nitrogen which has been changed over and over again from the original character in which it occurred at Joliet. How this change takes place I have tried to show in my description of the nitrogen cycle.

"Q. Are conditions worse or better in the Illinois River since the Drainage Canal was opened, carrying sewage from Chicago into the Illinois River, than they were prior thereto, when the Chicago sewage was pumped into the Illinois River by way of the Illinois and Michigan canal?

"A. I think the chart representing the Illinois River, May,

June, July and August, 1899 and 1900, which was produced in evidence yesterday, shows clearly the conditions in the Illinois River in comparable months in 1899 and 1900. (7448.) This chart compared the state of the river in corresponding periods in 1899 and 1900, and showed that the purification took place almost exactly in the same way during those two periods. Great amount of decomposition of organic matter between Joliet and Ottawa, the zone of greatest decomposition being in both years in the neighborhood of Ottawa. That purification in both years took place in a very similar way is shown by the close correspondence of the various curves for the two periods. The rapid rise in free ammonia, albuminoid ammonia and nitrogen as nitrites between Averyville and Wesley City showed in both periods, the pollution entering the river between these points. The curves then show a repetition of what took place between Joliet and Averyville, the re-purification of the river. All the data as given by the two charts showed that the purification of the river in the two years took place exactly in the same way, and also that the river at all points was purer during May, June, July and August, in 1900, than in 1899.

"Q. From all the analytical data which you have studied in this case, as well as your tables and charts offered in evidence, what are your conclusions as to whether or not the Illinois River purifies itself of sewage of Chicago before Grafton is reached?

"A. My opinion is, as has been shown by my answers to (7448) the previous questions, that I believe that the sewage of Chicago is entirely decomposed before Grafton is reached, and that the only effect that we perceive in the river at Grafton is the nitrogen contents and in high chlorine.

"Q. Are the nitrogen contents and the chlorine such as are found in the river at Grafton of themselves elements dangerous to public health?

"A. Not in the slightest degree. The chlorine and nitrogen content, as found in the river at Grafton, have, as far as we know, absolutely no effect upon the human system." (7449.)

Mr. John W. Hill, who had charge of the filtration plant at Philadelphia, made a compilation of the chemical and bacterial data taken from the tables prepared by the chemical and and bacteriological experts acting in behalf of the Sanitary District of Chicago, as they appear in the book entitled "Streams Examination," for the years 1899 and 1900, which tables appear on pages 7525 to 7528 of the printed record, and his testimony as to the condition of the Illinois River in 1899 and 1900 is set out in detail as follows:

"Q. What do these tables show?

"A. This table shows in the following order:

"An increase in the bacterial content of the water from Havana, Illinois, to Grafton.

"A decrease in the suspended matter from Wesley City to about one-fourth the distance from the Missouri shore into the Mississippi River, at Chain of Rocks.

"An increase in the total solids from Chicago to Grafton.

"A reduction in the total solids from the Mississippi River at Grafton to one-fourth the distance from the Missouri shore, at Chain of Rocks.

"An increase in the total solids from the Missouri shore of the Mississippi River to the Missouri shore at the St. Louis waterworks. (7528.)

"A reduction in the total solids of the Missouri River at West Alton.

"It shows, with two exceptions, a material reduction in the total oxygen consumed, which is, in my opinion, significant as indicating self-purification by natural processes during stream flow past the thirty-two stations named in the table.

"Number 18, Chandlersville, Sangamon River, shows an increase in the total oxygen consumed.

"Number 32, the Missouri River at West Alton, and all the other stations from the Illinois and Michigan Canal at Bridgeport, down to the Missouri shore of the Mississippi River at the St. Louis waterworks, show a reduction.

"Considering the nitrates and nitrites, which, in my opin-

ion, are always significant factors in showing changes taking place in the quality of polluted waters, and which, where purification, if being effected by sedimentation or filtration, or any other of the known practical means, not including sterilization by heat, the nitrites should diminish as the water is reduced in sewage pollution and the nitrates should increase.

"Considering the table before me, with the exception of four stations, namely, the Desplaines River at Joliet, the Kankakee River at Bloomington, the Illinois River at Morris and the Sangamon River at Chandlersville, the nitrites are largely decreased, and omitting nine stations, namely, the Illinois and Michigan canal at Bridgeport, the same canal at Lockport, the Desplaines River at Lockport, the Fox River at Ottawa, the Illinois River at Ottawa, the Illinois and Michigan canal at La Salle, the Illinois River at La Salle, the same river at Henry and the same river at Averyville, there is everywhere else a marked increase in the nitrates. If I was applying the information contained in the sheet showing the nitrates and the nitrites for 1899 and 1900, and the percentage of decrease and increase to the work of filtration, I should have no hesitation in claiming the same degree of purification by the filters as is here shown by self-purification or sedimentation in the channel of the river. Referring to the tables showing the chlorine, this has increased for all stations from the Illinois River at Kampsville down to the Missouri River at West Alton, excepting the intake of the St. Louis water in the Mississippi River, where the tables show a diminution of chlorine. Taking all the data together, and particularly that relating to the total oxygen consumed, and the nitrates and nitrites, I consider that the condition of the water flowing in the stream at Grafton has been improved." (7529.)

As touching upon the question of whether the chemical and bacterial surveys are sufficient to enable a sanitarian to pass judgment upon the waters of the Illinois, Mississippi and Missouri rivers, the following questions asked of Professor Jordan and answered by him are submitted for the consideration of the court:

"Q. In your opinion, is it possible to pass a competent judgment upon the waters of the Illinois, Mississippi and Missouri rivers, on the basis of the analyses you have submitted in your testimony?

"A. It is decidedly my opinion that such is the case. The analytical data, chemical and bacterial, that I have secured by these weekly, daily and hourly determinations extend over a sufficient interval of time, and include sufficiently varying conditions to permit of a satisfactory judgment being rendered as to the general character of the waters dealt with. The separate analyses number many thousands, and the results embody the experience gleaned from a study of high water and low water conditions, of summer and winter temperature, and of varying climatic and meteorological factors. It is my judgment that taking into consideration the analyses made concurrently by Professors Palmer, Long, Gehrmann, Zeit and Burrill no such extensive and exhaustive study of river water in connection with the problem of self-purification of streams has ever been made anywhere in the world as that carried out during this period." (6137.)

That the doctrine of self-purification of streams is not a novel one or applicable to the Illinois River alone is shown by the investigations of a number of European authorities.

The evidence in this case discloses the fact that according to the investigations made by Schlatter upon the Limmat that receives the sewage from Zurich, Switzerland, the zone of purification is nine miles from the source of pollution. (4467.)

The River Oder, at Breslau, also receives the sewage of the City of Breslau; 32 kilometers below the city it has the same number of bacteria again that it had before it entered the City of Breslau.

The Isar at Munich shows the zone of bacterial purification which is complete 33 kilometers below the City of Munich, of twenty miles. This is given in Prausnitz—Hygiene. (4469.)

The Spree in Berlin also receives sewage, which increases the bacteria to 1,000,000 per cubic centimeter. (7425.)

Then it goes into the small lake of Havel, and at the exit of that lake, or Sacrow, the bacteriological flora is again the same as it was in the River Spree before it entered the City of Berlin. This is given also in the Zeitschrift fur Hygiene, page 355, Volume 3. (See Zeit, 4468.)

And according to Comte Max Le Couppey de la Forest, the Secretary of the Commission d'Etudes des Eaux, Paris, France, who testified in this case regarding the River Seine; in 1869, when 800,000 people discharged their sewage in the River Seine, the zone of purification was perhaps 45 miles below Paris, but now we have perhaps 1,200,000 people who discharge their sewage into the River Seine, and the zone of purification is perhaps 55 miles below Paris. (4836.)

It will be noted that in all of these cases the distance in which purification is asserted to have taken place is much less than the distance between Chicago and Peoria, or Peoria and the intake tower of the waterworks of the City of St. Louis.

Perhaps the most remarkable and convincing manifestation or demonstration of the power of a river to purify itself is that afforded by the Mississippi at New Orleans, the details of which has already been given in this brief.

The doctrine of the self-purification of streams was employed by Dr. Teichmann in a most remarkable manner. In order to sustain his position that the sewage of Chicago affected the water supply of St. Louis, his analyses were held to disclose the fact that the Mississippi River at Grafton was a potable stream; that is, fit for drinking purposes and domestic uses, notwithstanding the fact that St. Paul, Minneapolis, McGregor, Prairie du Chein, Dubuque, Keokuk, Davenport, Rock Island and all the cities lying tributary to the Mississippi River empty their sewage into said stream, and notwithstanding the fact that the Mississippi has situated upon its water shed above St. Louis a population in cities of over five hundred inhabitants, of 1,839,586.

Professor Teichmann states, on page 1480, Vol. 2 of the Record:

"The analytical results from the water, as I have studied them, the water of the Mississippi River found a few miles above the mouth of the Illinois, allow of no other conclusion than that the water is potable," which, if his testimony is to be accepted, gives an illustration of the doctrine of the self-purification of streams, as the same operates in the Mississippi River above Grafton.

Again, the same witness adopts the doctrine of the self-purification of streams, in order to sustain his conclusions about Chicago, when he states (p. 1507):

"The chemical analyses of samples of water taken at Fort Bellefontaine show that whatever water pollution—whenever sewage pollution has taken place from the sewage of Kansas City, that sewage pollution has to such an extent disappeared that when the water reaches Fort Bellefontaine, after a run of 403 miles that water is potable at Fort Bellefontaine."

If the water of the Missouri River, as testified to by Dr. Teichmann when the same reaches Fort Bellefontaine, at the mouth of the Missouri, is potable, the conclusion is irresistible that the Missouri River, with a population in towns of over 500 inhabitants, of 1,650,549, emptying their sewage at points above, has purified itself by the time it reaches Fort Bellefontaine, a station located near the mouth of the Missouri, where Dr. Teichmann in his testimony (p. 1493) stated: "I would consider the water found at Fort Bellefontaine station potable throughout the year."

This same doctrine was employed by Dr. Teichmann in order to find an explanation for the pollution of the Illinois River by the Chicago sewage, as well as a theory for the elimination of the sewage from the Illinois River contributed to it by its tributaries and the cities exclusive of Chicago sewering into that stream.

Dr. Teichmann states, on page 1213, Vol. 2 of the printed record:

"In other words, if we take the sewage of the City of Peoria and run it into water at such a ratio of dilution, the sewage

would, in my opinion, after a run of from 25 to 50 miles, be sufficiently purified, with so much water added to the sewage, so as to remove the polluting effect of the Peoria sewage on that river."

Without giving endorsement to the views of Dr. Teichmann, hereinabove quoted, his views nevertheless demonstrate the necessity for him to adopt the doctrine of the self-purification of streams as applicable to the Missouri, Mississippi and Illinois rivers, in order for him to bring out clearly his conclusion that the sewage of Chicago, in volume and amount, polluted the waters of the Mississippi River. His testimony upon this point will be discussed in a subsequent part of this brief.

The evidence, which has been quoted and set out at length, sustains, corroborates and confirms the conclusion that the sewage of Chicago which passes into the Desplaines River through the Bear Trap dam at Lockport has become purified by the time that Peoria has been reached, and by the time the waters of the Illinois River reach Grafton. There is nothing remaining of the Chicago sewage but the chlorine and the mineral constituents, which, according to the evidence in this case, is not a dangerous element to be considered in sanitary problems.

The chemical and bacterial surveys made by the defendants in this case, comprehensive as they are, covering the period before the opening of the Drainage Canal, as well as the period subsequent thereto, demonstrates, scientifically, that the water of the Illinois, long before it reaches Grafton, has lost all of the impurities and pollution, which it had received from the Chicago Drainage Canal.

And the foregoing facts, as detailed in the evidence, establishes the proposition as clearly as any fact can be established by evidence that the water of the Illinois River at Grafton since the opening of the Drainage Canal, as disclosed by chemical and bacterial surveys covering a long period of time, is, if anything, in a better sanitary condition since the opening of the Drainage Canal than it was prior thereto.

Dilution.

The extent to which the dilution of the water of the Illinois River with the purer water of Lake Michigan has affected the sanitary condition of this stream is a matter worthy of consideration. The amount of infectious material in a given quantity of water is unquestionably affected by dilution, and in considering the effect of discharging the Sanitary Canal into the Desplaines River the influence of dilution cannot be ignored.

"Suppose that infectious material was introduced into sewage to such an extent that each tumblerful of the sewage contained one typhoid bacillus. Suppose, further, that such sewage were diluted with nineteen times its bulk of pure and uninfected water, it would then be true that out of one hundred glasses of this mixture of sewage and pure water only five would contain typhoid bacillus, instead of the whole one hundred, as was originally the case. In other words, the same effect is obtained as if ninety-five per cent. of the typhoid bacillus perished." (6167.)

Mr. Randolph has testified concerning the degree of dilution that is effected by the discharge from the Sanitary Canal. "I conclude that the natural pollution of the Illinois River, due to the urban and rural population draining into its watershed, exclusive of all sewage coming from Chicago, is greater than when the waters of the Illinois River are combined with the discharge from the Sanitary Canal after the opening of said canal. In the conditions which obtain, without considering the discharge from the Sanitary Canal, the pollution is one in 17.48. The pollution, considering the Sanitary Canal, is one in 34.3." (6648.)

The influence of dilution in this direction is, of course, obvious, and has been recognized by defendant's witnesses, as shown by the following citation from the testimony of Professor Sedgwick:

"Q. Well, if the cities or towns below St. Louis, on the Missouri side of the Mississippi River, should take their water

supply from the Mississippi River, they would be affected by the sewage of St. Louis, would they not?

"A. You say on the Mississippi side?

"Q. I mean on the Missouri side.

"A. They would, unless the dilution was so great that the sewage of St. Louis was lost in the volume; I should suppose that they would be affected.

"Q. You do not attach much importance to dilution alone, do you?

"A. Very great." (2256-57.)

Was the Opening of the Drainage Canal Immediately Manifested by a Change in Conditions Observed at St. Louis?

The defendants, in reply to the testimony introduced in this case by Dr. Ravold and Dr. Teichmann, to the effect that immediately following the opening of the Chicago Drainage Canal on January 17, 1900, the sewage and sewage mud coming from Chicago was manifested in the Mississippi River from Grafton to the St. Louis intake, desire to submit the testimony of Professor A. W. Palmer, who testified upon this subject upon cross-examination as follows:

"Q. Professor, do your analyses show in any way whatever the effect of the sewage and sewage mud coming from Chicago down the Illinois River caused by the opening of the Drainage Canal, January 17, 1900?

"A. They do not, in my opinion." (5689.)

"So far as the assumption of a black sewage muddied condition of the Illinois River water throughout its length or at various points along it, and the same condition, including Grafton and the Mississippi River between Grafton and the chain of rocks is concerned, I would state as my opinion that such assumption is altogether beyond the fact, that no such condition was to my knowledge observed along the course of the Illinois River, nor at Grafton, nor in the Mississippi River between Grafton and the chain of rocks, but that, on the other hand, the results of my analyses, particularly those having to

do with the appearance and the odor of the water, indicate that no such condition maintained or held except that in the upper stretch of the Desplaines River in the vicinity of Joliet the odor of the water as recorded in Table 44 of the series of analyses I have submitted as gassy, from January 2d to March 26th, 1900, and that the water in the Illinois River at Morris, collected upon January 26th, 1900, had an odor which is indicated as gassy. There is nothing else in the series of analyses included in my tables which indicates directly a more than usually large proportion of sewage contained in these waters. On the other hand, the variations in color and in the proportions of suspended matters and in the color of the suspended matters contained in the water during this period, were not different from those observed in other years in like seasons. I would further add that I obtained from the various collectors of water samples along the river information concerning the appearance of the water at this time, and in no case did they note an unusually dark or black sewage colored mud contained in the water. They failed to note anything particularly different from the usual appearance during the season of high water in the Illinois River in the spring." (5692.)

On re-direct examination he testified:

"Q. Professor, to what do you ascribe the fact mentioned in your testimony, that no unusual appearance of black sewage muddiness occurred in the waters of the Illinois River, just after the opening of the main drainage channel upon January 17th, 1900, and that the data of your chemical analyses show no unusual conditions of these waters for the season in question?

"A. In general I ascribe this to two conditions or circumstances. In the first place the water or the sewage began to flow from the Chicago River into the drainage channel in the early morning of the 2d day of January, 1900, and slowly passed into the same during the following twelve days, so that the drainage channel was filled with such discharges, including water drawn through the river from the lake, by the 14th of

January, and that during this period of slow dilution and standing in the Drainage Canal and the subsequent period of three days, during which it stood quiescent in the canal, septic action took place which would tend to destroy much of the organic matters contained therein, and prepared it for the more speedy destruction after it had mixed with the natural waters of the Desplaines and the Illinois, the amount of dilution, taking the whole cubic contents of the Chicago River as the basis of comparison and the cubic contents of the sanitary canal, showing that the dilution during the filling of the sanitary canal amounted to 7.84. That is to say, the water of the Chicago River, which was introduced in the canal, amounted to one part as against 6.84 parts of lake water drawn through the Chicago River while the contents of the Chicago River were being drawn into the Drainage Canal.

"The other general condition I referred to previously in my testimony. It is that just at the time and immediately following the opening of the gates at the Bear Trap Dam at Lockport, which permitted the first discharge from the sanitary canal into the Desplaines and thence into the Illinois River, namely, upon January 17th, 1900, there was rain, and the stages of water in the Illinois River throughout its course were increased; that is, the waters were raised from the volume brought into the stream from its natural water-shed, tributaries and its own banks. The rise at Averyville at this time, as between the 17th of January, 1900, and the following days, amounting to .6 of a foot—that is, from the stage of 5.1 feet upon the 17th of January, the water rose to the stage of 5.7 upon the 18th; to 6.1 upon the 19th; to 6.6 on the 20th; to 7.1 upon the 21st; to 7.5 upon the 22d; to 7.7 upon the 24th; 8.15 upon the 25th; same height for the next two following days, that is the 26th and 27th; it fell to 7.9 feet upon the 28th, a rise of 3 feet at this point between the 17th day of January and the 25th." (5702.)

This testimony, which is so conclusive upon the subject, requires no comment when consideration is given to the fact that

no witness who testified in this case had a better personal knowledge of the conditions obtaining upon the Illinois River water-shed than Professor Palmer.

The Potability of the Desplaines River Water According to Dr. Teichmann.

A striking illustration of the way in which chemical analyses of a water may be interpreted differently according to the knowledge of local conditions possessed by the observer is shown in Dr. Teichmann's inference concerning the potability of the Desplaines River water.

"At times there are no nitrites in this river, and since there is such a small amount of free ammonia in that river and the chlorines are exceedingly low, we must call this—the Desplaines River before it is polluted by the sewage from the Drainage Canal and the sewage from the Illinois and Michigan Canal, a comparatively potable river water." (Teichmann, 1258.)

In contrast to this interpretation placed by Dr. Teichmann upon the results of his chemical analyses for the Desplaines River water may be placed the statements by Professor Long on this same matter. Professor Long testified (4167):

"I am familiar with the Desplaines River from the point where it joins with the canal near Joliet, above Joliet, to a point many miles north of Chicago, where the river flows out from a certain swampy region. I am familiar with the towns on the river and the character of the drainage entering the river. The Desplaines River is a sluggish stream, which drains a number of suburban towns around Chicago. One of these is the Town of Riverside, which is not far above the controlling works at Summit, north of Summit. The Town of LaGrange is also in part drained into the Desplaines, the sewage of La-Grange flowing into a small stream, a small creek, which in turn enters the Desplaines near Riverside. Above Riverside there are several towns located on the Desplaines, the drainage of which is taken up by that stream. Maywood is one and Norwood Park is another. The Desplaines furnishes the only out-

let for drainage for these various towns, and before it becomes mixed with the canal water it is not a potable stream, and has not been in a great many years, not in twenty years."

"From my analyses and from my present knowledge of the Desplaines River above Lockport, and of the towns that empty their sewage into the river, I do not consider that the water is a safe and potable water." (4168.)

Chlorine in the Missouri River at Its Mouth Due to Sewage Pollution and not to Salt Beds on the Kaw River.

The inference was drawn by Dr. Teichmann (1250) on the basis of two samples of water taken from the Kaw River, which empties into the Missouri just above Kansas City, that the chlorine in the Missouri River was derived from salt beds in the territory through which the Kaw flows. This opinion was evidently communicated to Messrs. Keiser (1722) and Whipple (2091), who adopted Dr. Teichmann's view without, so far as the testimony shows, making any investigations on their own account. It was surmised from the two analyses made by Professor Teichmann that the water of the Kaw was salt laden, and was responsible for the large amount of chlorine shown in the analyses of all observers to be present in the Missouri River at its mouth. In addition to these two samples he drew conclusions from United States Government reports in regard to salt beds in that part of the country.

On account of the special emphasis laid upon this assertion by Dr. Teichmann, Professor Keiser and the other witnesses of complainant who testified in this case, reference to whose testimony will be subsequently made, the defendant, the Sanitary District, sent two men to collect samples of water from the Kaw River above Kansas City, Kansas, from the Missouri River above Kansas City, Missouri, and from the Missouri River below Kansas City, Missouri. In all thirty-six samples were taken in such a way as to give representative cross sections of the stream at the points indicated.

These samples of water, collected with the usual precau-

tions, were sent to the laboratory of Professor John H. Long, in the City of Chicago, where they were examined to determine the amount of chlorine present. The results of these analyses are set forth in full in Professor Long's testimony (4245-6). The averages as drawn from these tables show a considerably larger figure for chlorine below Kansas City than in the Kaw or in the Missouri above Kansas City.

The excessive chlorine below Kansas City is more than can be accounted for by any addition from the Kaw, and shows that a certain proportion must come from the stock yards industries and the sewers of Kansas City. (4247.) As a matter of fact, the volume of the Missouri River is very considerably greater than the volume of the Kaw throughout this period, and the amount of chlorine in the Kaw, taking its volume into consideration, cannot act to increase the amount of chlorine in the Missouri above the figure given for the Missouri above Kansas City. The chlorine at the mouth of the Missouri River can be attributed only in part to the chlorine of the Kaw River, the tables showing that the additions from Kansas City are an important factor. At the time the examinations were made the analyses showed considerably less chlorine above Kansas City than below Kansas City (4248), and the chlorine below Kansas City is considerably greater than the chlorine in the Kaw. (4249.)

It is, therefore, plain that the excessive chlorine in the Missouri River at its mouth must be, at least in part, attributed to sewage pollution rather than to the salt beds of the Kaw, as alleged by Dr. Teichmann. That this is really the case is further shown by the important evidence obtained from the determination of the number of organisms belonging to the group known as bacillus coli communis, which are contained in the water of the Missouri River at Fort Bellefontaine. The chlorine determination, when taken in conjunction with the presence of bacillus coli communis in large numbers in the Missouri River at its mouth, shows that this river must be regarded as a sewage-polluted stream, and is not the pure, whole-

some and potable water it is represented to be in the testimony of Dr. Teichmann and Professor Keiser. The nature of the evidence upon which the witnesses for complainant have formed the opinions that they have expressed is shown by the following excerpts from the testimony of Mr. Whipple and Professor Keiser:

"Q. Do you regard chlorine in the Missouri River as an evidence of sewage pollution?

"A. From what I know of the existing conditions on the water-shed of the Missouri River, and from the fact that there are certain salt deposits, there are said to be certain salt deposits on portions of that water-shed, and from analyses which I have seen showing the indication of such salt deposits, of the effect of such salt deposits on the water of the Kaw River, it is my opinion that the chlorine in the Missouri River, in its low reaches, cannot be used as an index of pollution." (Whipple, 2091.)

"Q. You stated in explanation of the fact that the chlorines run high in the Missouri River that there was some river in Kansas that was supposed to be impregnated with saline matter. Will you state what that river is?

"A. I am not personally acquainted with the exact source, but I have been informed by the city chemist of the City of St. Louis, Dr. Teichmann, here that one of the tributaries of the Missouri, coming in at Kansas City, has gone across salt beds in Kansas, and that is very highly charged with chlorine, and that is the reason for chlorine in the Missouri River.

"Q. You don't know anything about that except what Dr. Teichmann told you?

"A. No, sir.

"Q. You never made any analyses then of this Kansas river water?

"A. I have not.

"Q. Before it came into the Missouri River?

"A. No, sir.

"Q. You have no opinion then upon the subject so far as

that is concerned, simply what you were told by the city chemist?

"A. Simply what I was told by the city chemist, who, I believe, has made these analyses.

"Q. Now, if it should appear by analyses that the river from Kansas, coming in from Kansas City, which I believe is called the Kaw?

"A. Yes, I think that's it.

"Q. That is, if it did not run any higher in chlorine than the waters of the Missouri River above that point, then the theory as to chlorine constituents coming from Kansas would not obtain?

"A. That is so, I agree to that." (Keiser, 1107.)

"Q. Now, you assume in defense of the Missouri River, that its chlorines are entirely from mineral deposits in the river in Kansas?

"A. No, sir; not entirely.

"Q. Well, very largely?

"A. Yes. There is so much there that the chlorine is no longer of service to us in judging of the amount of pollution in the water.

"Q. You wouldn't admit that any portion of the chlorine in the Missouri River showed the presence of sewage in the Missouri River?

"A. Yes, sir.

"Q. What portion do you think in the Missouri shows the presence of sewage?

"A. I couldn't say; I don't know.

"Q. You have no idea?

"A. No idea.

"Q. As a chemist, and without reference to this question, if you had been called upon to analyze a sample of Missouri River water, not knowing that it was Missouri River water, and not knowing that you were a chemist of the City of St. Louis, would you have said, considering the high chlorine in that sample, that it was potable water?

"A. I would have been inclined from the high chlorines to condemn that water as unpotable." (Keiser, 1722.)

Reference to the testimony of Professor Keiser and Mr. Whipple, together with their source of inspiration, Dr. Teichmann, to the effect that the chlorine in the Missouri River is attributable, not to sewage pollution, but to the salt beds of the Kaw, when taken in connection with the established facts based upon scientific investigation, shows, to use the language of Professor Sedgwick, that chlorine "is a very weak reed to lean upon" in order to explain away the evidence of sewage in the Missouri River at Fort Bellefontaine. If in the entire testimony in this case a weaker reed can be found than the chlorine of the Kaw, which was so eagerly grasped by these learned experts in explaining the lack of pollution of the Missouri River, the defendants in this case have failed to discover it.

Professor Keiser's Chemical Deductions.

Complainant in its brief filed in this case on pages 193 to 205 quote in full the testimony given in this case by Professor Keiser. It is interesting to note that the testimony of Professor Keiser, upon which the complainant relies in part to establish the effect of the sewage of Chicago upon the water of St. Louis is taken from the testimony of Professor Keiser upon analyses which he did not make, and had no personal knowledge as to how the samples were collected, how or when analyzed, but procured them from a message of the Mayor of St. Louis. His testimony on that point is very interesting and is herewith submitted:

"I obtained the data from the Water Commissioner of St. Louis, Mr. Edward Fladd, and from the office of the city chemist, Dr. Teichmann. I received from Dr. Teichmann also some data from my own laboratory, the Washington University Chemical Laboratory." (1698.)

Against the objection of the defendants as to the introduction of this evidence the data was submitted in evidence.

The cross-examination, which is very interesting and instructive, is as follows:

"Q. By whom were the seventeen analyses from the distributing well made in the period ranging from May 2d, 1893, to January 4th, 1894?

"A. They were made by the Water Department of the City of St. Louis, Mr. M. L. Holman Water Commissioner.

"Q. Where did you obtain these figures?

"A. I obtained these figures from the annual report of the Mayor of St. Louis for 1894, page 418.

"Q. You know nothing whatever as to the time of the analyses of any of these samples prior to January, 1900, with reference to their being taken from the water?

"A. Yes, the dates are all stated for those in that report from the Mayor's message of 1894, and also these others that are recorded below. The date when the samples were taken is always indicated.

"Q. Have you any knowledge of that fact?

"A. None except what is stated in the report of the Water Commissioner.

"Q. As to any of these samples in the paper described in group D and group C, can you tell at what time they were taken from either the distributing wells or from the clear wells, and how long a time elapsed until they were analyzed after they were taken?

"A. No, sir.

"Q. Do you know personally anything in reference to the manner in which those samples were kept for the purposes or plan by which they were analyzed?

"A. Yes, sir.

"Q. I mean, do you personally know anything about it?

"A. No, except what I have read in that report. The method of the analyses is there described.

"Q. Your knowledge then in reference to it is derived from the report?

"A. Yes, sir.

"Q. And your knowledge as to that is derived from the printed copy of the report?

"A. Yes, sir." (1712.)

From the foregoing testimony it seems remarkable that after the chemical examination conducted upon the Illinois River by Professor Keiser and Dr. Teichmann counsel for complainant should rely upon incompetent evidence taken from the Mayor's message to the Water Commissioner of St. Louis, in order to show the effect of Chicago sewage upon the water supply of St. Louis. And it is a significant fact, deserving of criticism, that Professor Keiser, who confounded Wesley City with Peoria Narrows in drawing comparisons between his analyses and those of Professor Long, should have introduced into the evidence in this case chemical analyses taken from the Mayor's message in the absence of any proof as to where the samples were taken, how taken, when taken, or how soon after taken they were analyzed, and into the analyses that he introduced into this case no reference was made to oxygen consumed, total solids in suspension or solution, no reference was made to chlorine determinations, and the explanation offered by him is found in the answer to the following question:

"Q. In your opinion chlorine does not enter into the proper consideration of the potability of water?

"A. Not of the St. Louis water." (1713.)

The defendant assumes that the reason why chlorine does not enter into consideration of the potability of St. Louis water, especially the Missouri River, is found in the question and answer given by Professor Keiser, on page 1050:

"Q. Is it that (chlorine) that affects the flavor of the Missouri water?

"A. I think it does."

Defendants submit that the testimony of Professor Keiser, quoted by complainant in its brief, as above referred to, is not only incompetent evidence, and should not have been offered or admitted in the evidence in this case, and hence should not be considered by the Court, and it seems incredible to the de-

fendants that the array of distinguished counsels representing complainant in this case should place such special emphasis upon this incompetent evidence in order to attempt to establish a fact which the entire evidence in this case proves beyond all question of a doubt to be just the opposite, viz., that the sewage of Chicago does not manifest itself by the time the waters of the Illinois River reaches the Mississippi.

V.

THE ILLINOIS RIVER, AT ITS MOUTH, FROM A SANITARY STANDPOINT, BASED UPON CHEMICAL AND BACTERIAL ANALYSES, IS LESS POLLUTED AND LESS DANGEROUS TO HEALTH THAN IS EITHER THE MISSOURI RIVER OR THE MISSISSIPPI RIVER; AND THE ILLINOIS RIVER, EMPTYING INTO THE MISSISSIPPI AND MISSOURI RIVERS, IS CONTAMINATED AND POLLUTED BY THESE TWO RIVERS, INSTEAD OF CONTAMINATING AND POLLUTING THE COMBINED WATERS OF THE MISSISSIPPI AND MISSOURI RIVERS.

The chemical and bacterial surveys, which have already been discussed in this brief by defendants, disclosed the sanitary condition of the Illinois River, for periods before the opening of the Chicago Drainage Canal and since, to be in a better sanitary condition at Grafton since the sewage of Chicago was diluted with the pure water of Lake Michigan than it was during the preceding period.

In order to ascertain what sanitary effect the waters of the Illinois River, since 1900, have upon the combined waters of the Mississippi and Missouri, as the same pass the St. Louis intake located at the Chain of Rocks, the defendants in this case, in conjunction with its other investigations, made a bacterial and chemical survey of the waters of the three rivers before and since the opening of the Chicago Drainage Canal, together with a chemical and bacterial survey of the waters of the Mississippi River, as the same pass the St. Louis intake located at the Chain of Rocks.

In addition to the investigations heretofore detailed in this brief, an agreement was made and carried out between the Sanitary District and the City of St. Louis, to make analyses of the waters of the three rivers, in 1901. Dr. Ravold appeared before the Board of Trustees, as representing the interests of the City of St. Louis. Laboratories were established at Peoria, Grafton and St. Louis. The samples were collected in the rivers by

water takers for Chicago and St. Louis experts, at the same time and place. A Chicago and a St. Louis bacteriologist plated the samples in the same room, so that the samples were plated immediately when brought ashore.

The City of St. Louis furnished a good room, and the City of Chicago paid for some of the heat. A laboratory was established at 1141 Market Street, for St. Louis, and for the City of Chicago on Locust Street in the City of St. Louis, and the collectors went out together to the Chain of Rocks.

(See Dr. Ravold's testimony, pp. 214, 218 and 911.)

Prof. E. O. Jordan, of the University of Chicago, was selected by the Sanitary District, and he had charge of the laboratories located at Peoria, Grafton and in the City of St. Louis.

(See Vol 7, p. 6041.

The defendants contend that the chemical and bacterial examinations conducted on the part of the defendants, as well as by the complainants in this case, establish the fact to be that since 1900 the sanitary condition of the Illinois River at Grafton shows less pollution and contamination than does the Mississippi above Grafton, and that the Missouri River at its mouth is more polluted and infected than is the Mississippi or the Illinois River above Grafton.

The evidence in this case demonstrates and sustains the assertion that the Mississippi and Missouri pollute the waters of the Illinois River, rather than that the waters of the Illinois pollute the combined waters of the Missouri and the Mississippi.

The testimony of Professor Jordan upon this proposition is set out in detail as follows:

"Q. What determinations were made in these different laboratories?

"A. The work done during this period was wholly bacteriological in character, and may be grouped conveniently under three heads:

"(a) The determination of the number of bacteria in the river water as shown by the ordinary colony counts.

"(b) The number of germs of the colon group in the river water as shown by the dextrose fermentation tube test.

"(c) Study of the species of bacteria isolated from the river water." (See Vol. 7, p. 6043.)

In carrying out this line of work for the colony count at Averyville, above Peoria, the results were placed in tabular form, and appear on pages 6046 to 6049, Vol. 7 of the printed record.

"Q. Will you state what the table that you have just read shows, and its sanitary significance?

"A. This table contains the results of daily bacterial determinations made upon samples of water from the Illinois River at Averyville between October 9th and December 30th, 1901. On this table are specified the date of collection, the hour of collection and the hour of plating, the temperature in degrees centigrade of the water and air; the height of water; the dilution in which the sample was plated; the number of colonies per cubic centimeter (two samples in most cases), and the average of these daily determinations. Throughout October and November the numbers of bacteria in the water, as shown by the colony count, were low, the counts showing often only a few hundred colonies per cubic centimeter. In December the numbers increased somewhat, and in the latter part of December the numbers are on several occasions in the tens of thousands.

"So far as the bacterial count is concerned, these examinations show that the water of the Illinois River at this point was in a condition which, considered as a river water, was fully up to the average of river waters in this country." (6049-6050.)

The tables for the colony count for the station at Pekin, below Peoria, appear in the printed record on pages 6051 to 6053.

"Q. What does this table show and what is its sanitary significance?

"A. This table shows the results of colony counts made

from samples of water collected from the Illinois River at Pekin between October 16th and December 13th, 1901, the same data being given as in the table for Peoria.

"Throughout this period this water is characterized by a much higher bacterial content than the water of the Illinois River at Averyville. On October 26th, for example, the average number of four determinations at Pekin was 341,000 per cubic centimeter, while at Averyville on the same date there were only 890 colonies per cubic centimeter." (6054.)

The tables for the determination of a like character at Grafton on the Illinois River appear at pages 6054 to 6058.

"Q. Will you state what the table you have just read shows, and its sanitary significance?

"A. This table contains the result of bacterial counts made from samples of water taken from the Illinois River at Grafton, between October 1st and December 24, 1901. The data specified as given in the Peoria tables are given also in this table.

"The numbers of bacteria per cubic centimeter found in the water of the Illinois River at Grafton are very similar to those found in the water of the Illinois River at Averyville." (6059.)

The tables for a similar investigation on the Mississippi River above Grafton appear on pages 6059 to 6063.

"Q. Will you state what the table you have just read shows, and its sanitary significance?

"A. This table contains the tabulations of colony counts made from samples of water obtained from the Mississippi River at Grafton between October 1, 1901, and December 24, 1901, other data specified in the Peoria tables being also included in this table. Throughout most of the period covered the results correspond rather closely with those obtained from the Illinois River at its mouth." (6064.)

Tables for the Mississippi River in cross-section at the Chain of Rocks on the Illinois shore, mid-stream, intake tower, Missouri shore, appear on pages 6064 to 6076, inclusive.

"Q. State what those tables show and their sanitary significance.

"A. These tables contain tabulations of colony counts made from samples of water taken from the Mississippi River at the Chain of Rocks between October 7, 1901, and December 14, 1901, at four points across stream, namely, those specified in the records of the cross-section at this point for 1899 and 1900. These tables show that throughout the period covered the number of bacteria contained in the water taken from the Mississippi River at the intake tower and from the Missouri shore contained a noticeably larger number of bacteria than the water on the Illinois shore." (6077.)

Tables of the Missouri River for the colony count at Bellefontaine, or West Alton, appear on pages 6077 to 6080.

"Q. State what the table shows and its sanitary significance.

"A. This table contains tabulations of colony counts made from samples of water collected from the Missouri River at Fort Bellefontaine, between October 9th and December 16, 1901; other data being included as hereinbefore specified. It shows that throughout this period the number of bacteria in the water of the Missouri River at this point was noticeably higher than in the water of either the Illinois River at its mouth, or the Mississippi River above Grafton." (6080.)

A table of averages, based upon the tables heretofore referred to, appears on page 6081.

"Q. State what this table of averages shows and what conclusions you draw from it from a sanitary standpoint.

"A. This table contains the averages of the colony counts made from the water of the Illinois River at Averyville, at Pekin and at Grafton; from the Mississippi River at Grafton, and in cross-section at the Chain of Rocks, and from the Missouri River at Fort Bellefontaine. The number of bacteria found at Averyville and at Grafton was not dissimilar. These averages were higher than the average for this period in the Mississippi River. The usual winter increase which occurs in river waters took place this year in the Illinois River before making its appearance in the Mississippi. Up to the middle

of December, 1901, the two waters were very similar as regards their bacterial content. Throughout the whole of the period studied, the average number of bacteria, as shown by the colony count in the water of the Missouri River at West Alton, was several times as great as the water in either the Illinois River at its mouth or the Mississippi River above Grafton. The number of bacteria in the Illinois River at Pekin, as shown by these averages, was greatly in excess of that found at any other of the collecting stations, as in my opinion naturally follows from the entrance of the sewage and refuse of Peoria into the river above this point." (6081.)

A table of averages for the cross-section of the Mississippi River at the Chain of Rocks for the colony count appears on pages 6082 to 6083.

"Q. Will you state what the table shows, and its sanitary significance?

"A. This table contains the results of the bacterial counts made upon samples of water taken from the Mississippi River at the Chain of Rocks. The averages are arranged in their proper relation, namely, the Illinois shore, mid-stream, intake tower and Missouri shore, the count for the Missouri River being contained in the right hand column. These figures show that during the period covered by this investigation the number of bacteria in the water of the Mississippi River at this point was much lower on the Illinois shore than on the Missouri shore. It shows, moreover, that the water of the intake tower during the period partook of the character bacterially of the water of the Missouri River and of the Mississippi River on the Missouri shore. In other words, during these three months of 1901, judging from the bacterial content of the Missouri River and of the Mississippi River at this point, little if any, water from the Illinois River entered the intake tower of the St. Louis waterworks. It is evidence, also, from the bacterial count, that if any water from the Illinois shore did pass into the water intake, it improved the condition of this water, so far as reducing the number of bacteria per cubic centimeter was concerned." (6084.)

In addition to the foregoing tables, a series of photographs, illustrating the different cross-sections of the Mississippi River at the Chain of Rocks, was introduced in evidence.

These photographs shows the number of colonies developed in different samples of water collected in this cross-section.

"These photographs are thoroughly representative of the results obtained at the Chain of Rocks throughout this period, October, November and December, 1901, and show clearly that the mingling of the water from the Illinois shore of the Mississippi River with the water of the Missouri River would tend to diminish the number of bacteria per cubic centimeter in the latter water." (6085.)

"These photographs show, also, that in case any water from the Illinois shore of the Mississippi River intermingled with the water of the Missouri River at this date, it would decrease the number of colonies developing per cubic centimeter as shown in the table of averages for this cross-section at the Chain of Rocks during the period of 1901." (6089.)

(See Vol. 7, pp. 6045 to 6092.)

In addition to the colony count, Professor Jordan made a coli determination in 1901, during this same period, from the Mississippi River above Grafton and the Missouri at Bellefontaine, and a cross-section of the Mississippi River at the Chain of Rocks, at four places, the Illinois shore, mid-stream, intake tower and Missouri shore.

"Q. What purpose did you have in view to be subserved in making determinations for the bacillus coli communis?

"A. The relative abundance of the colon bacillus in water I consider as affording the most satisfactory indication of the sanitary quality of such water. In my opinion, this is the judgment of most sanitary experts at the present time. In a paper entitled, 'The Significance of Bacteriological Methods in Sanitary Water Analysis,' published from the Biological Laboratories of the Massachusetts Institute of Technology, by C. E. A. Winslow and C. P. Nibecker, and printed in the Technology Quarterly, Volume 16, No. 3, September, 1903, appears the following statement:

"'Colon bacilli are either wanting in good waters or are so rare as not to be found in the examination of samples of one cubic centimeter; they are found in a majority of one cubic centimeters of water so polluted as to be dangerous for drinking; between these two extremes their numbers vary with the amount of pollution. Klein and Houston in England, Jordan and Winslow and Hunnewell in America, and, very recently, Petruschky and Pusch in Germany, have exhaustively studied the distribution of the colon bacillus with uniform results, and that the absence of this organism demonstrates the harmlessness of a water as far as bacteriology can prove it, no one would probably hesitate to acknowledge; and that when present its numbers form a trustworthy measure of its sanitary condition, the observers above quoted have proved beyond reasonable cavil.'

"This statement represents my own judgment in the matter as well as what is the prevailing opinion among sanitary experts generally, and it is for this reason that in my studies into bacteriological conditions existing in the waters above mentioned, I have paid particular attention to the presence and relative abundance of the colon bacillus.

"Q. What methods did you employ in the determination of the colon bacillus in this examination made in 1901?

"A. I employed a method known as the Dextrose Fermentation Tube Method. Exhaustive comparative tests were made with the dextrose fermentation tube methods, with the neutral red method, with the carbol broth method, and other methods sometimes used in making this test, with the result that the dextrose fermentation tube method proved the most reliable.

"The method consisted in inoculating measured quantities of the water to be tested in fermentation tubes containing ordinary nutrient broth with an addition of one per cent. dextrose.

"The interpretations adopted for the changes so produced were as follows:

"Positive reactions, that is, those indicating presence of

B. coli were regarded as those tubes showing the gas production of over twenty per cent. of the tube length; the tubes yielding on absorption with sodium hydroxide a gaseous residue appreciably in excess of the carbon dioxide observed. Negative reactions were those showing:

"(a) No gas production, or

"(b) Gas production less than ten per cent. of the tube length.

"The doubtful class was made to include:

"(a) Those tubes yielding only ten to twenty per cent. of gas, and

"(b) Those yielding more than twenty per cent. before that appreciable excess of carbon dioxide.

"A series of fermentation tubes was examined in detail to determine the limits of accuracy of this method, with the result that out of 63 tubes examined, in 39 cases where the interpretation was positive typical bacillus coli communis was isolated from the tube and identified in all its biological characteristics.

"In seven cases where the presumptive test yielded a positive result the bacillus coli was not isolated. This may have been, and, in my opinion, was, because the colon bacillus, after producing its characteristic fermentation changes, was subsequently overgrown by other forms, such as the sewage streptococcus.

"In nine cases where the interpretation was doubtful the colon bacillus was not isolated.

"In four cases where the interpretation was doubtful typical bacillus coli was isolated.

"In four cases where the interpretation was negative the bacillus coli was not isolated.

"It may be added that these last named cases were those showing less than 10 per cent. of gas in which gas forming organisms not B. coli were isolated. In addition, some 20 tubes were examined which showed growth in the closed arm, but yielded no gas producing organisms of any kind.

"These results, in my opinion, show conclusively that where

a large number of water samples are treated the error due to relying on the presumptive test alone is not unduly large.

"The specific application of this method to the problem of self-purification of streams depends upon ascertaining in each case the dilution at which the tests give uniformly positive and that at which it gives uniformly negative results. This method which rests upon the determination of the relative abundance of the colon bacillus, is an extremely delicate test for recent sewage pollution.

"Winslow and Nibecker, in the paper just referred to, on the significance on bacteriological methods in sanitary water analyses, state, on page 237, 'In the second place, the bacteriological methods are far more delicate than in the others. Klein showed by experiment with dilutions of sewage that the colon test was from 10 to 100 times as successful as the methods of chemical analysis.'

"Studies of the self-purification of streams have confirmed these conclusions on a practical scale. Thus, 'in the Sudbury River it was found that, while the chemical evidence of pollution persisted for six miles beyond the point of entrance, the bacteria introduced could be detected for four miles further.'

"This latter statement refers to the study of self-purification in the Sudbury River, in Massachusetts, carried out by A. G. Woodman, C. E. A. Winslow and P. Hansen, and published in the Technology Quarterly, Volume 15, 1902, page 105." (See Volume 7, pages 6093 to 6096.)

The results of the colony determinations for the different stations under investigation, together with the table of summaries, were put in tabular form and are found on pages 6097 to 6120.

"Q. What sanitary significance do you attach to your tables of coli determinations, considered as a whole?

"A. In my opinion, the fate of the colon bacillus in running water furnishes a very satisfactory indication as to the degree and rate of self-purification in such water.

"The fact that the colon bacillus is present in but 43 per

cent. of the .1 cc. examinations from the Illinois River at Averyville, while it is present in 100 per cent. of the .1 cc. samples taken from the Illinois River at Pekin and in only 13 per cent. of the .1 cc. sample taken from the Illinois River at Grafton, shows not only the extreme delicacy of this test for sewage pollution, but shows a very considerable improvement in the sanitary quality of the water occurs between Pekin and Grafton, notwithstanding the large amount of pollution at Pekin. Comparing the condition of the water in the Mississippi River above Grafton, as evidenced by the colon content of these two waters, it appears that the colon bacillus was present in five per cent. of the determinations made of .01 cc. of water from these two places.

"It may be mentioned that 117 determinations were made of the Illinois River water above Grafton and 115 of the Mississippi River water above Grafton during this period, so that the substantial agreement in percentage shown in the sanitary character of these waters during this period has a satisfactory statistical basis.

"Comparing the examinations made of .1 cc. of water during this same period, it is shown that 24 per cent. of the samples from the Mississippi River yielded positive results, while 13 per cent. of those from the Illinois River above Grafton yielded positive results.

"In 1. cc. of water from thes two stations 38 per cent. of the samples from the Mississippi River and 30 per cent. of those from the Illinois River gave positive results.

"In other words, so far as any conclusion as to the sanitary character of these waters can be drawn from the colon determinations, and I have already indicated that in my opinion, and in that of sanitary experts generally, the colon test is the most delicate and satisfactory clue that we have to the sanitary condition of the water—the water of the Mississippi River above Grafton during this period was, if anything, of a less wholesome character than the water of the Illinois River above Grafton.

"Comparing further the colon content of the Missouri River water above Bellefontaine during this period, it is shown that 19 per cent. of the .01 cc. samples were positive, as compared with five per cent. in the Illinois River at Grafton, and that 50 per cent. of the .1 cc. samples were positive, as compared with 13 per cent. in the Illinois River at Grafton, and that 79 per cent. of the 1. cc. samples were positive, as compared with 30 per cent. in the Illinois River above Grafton.

"Comparing the percentages of positive results obtained in the examination of 1. cc. of water in cross-section at Chain of Rocks, it appears that there was a smaller percentage of colon bacteria in the Mississippi River on the Illinois shore and in mid-stream than at the intake tower and on the Missouri shore. This confirms the difference already noted between the colon content of the Illinois River and the Mississippi River at Grafton, and that of the Missouri River at Bellfontaine. The higher colon content of the Missouri River betrayed itself in the larger number of colon bacilli found in the Mississippi River at the intake tower and near the Missouri shore at the Chain of Rocks.

"The sanitary significance which I attach to these findings is based on what I have been able to learn by my own observation and experiments regarding the significance and relative abundance of the colon bacillus in waters of various kinds, as well as that derived from an examination of the available literature on the subject and the opinions of various sanitary experts already referred to in my testimony. It may be summed up by the statement that the water from the Missouri River during this period was distinctly more dangerous and unwholesome than the water of either the Illinois or the Mississippi River at Grafton, and, further, that the difference between the Illinois River above its mouth and the Mississippi River above Grafton, while not great, shows that on the whole the Illinois River was in a less highly polluted condition than the Mississippi." (See Vol. 7, pages 6121 to 6123.)

Professor Jordan had prepared and introduced in evidence

a series of photographs of fermentation tubes, which illustrate and illuminate the conclusions which he has drawn from the coli determinations.

These photographs appear on pages 6125 to 6131 of the printed record.

"Q. What is the character of the different waters?

"A. The character of these waters during this period, as shown by the colon examinations and as set forth in the tables and illustrated by the photographs, is quite different. The colon content of the Missouri River is markedly higher than that of either the Illinois or the Mississippi River at Grafton, and from this *I infer that during this period the Missouri River was more highly charged with dangerous bacteria and was distinctly less safe than the water of the Illinois River.*

"Under these conditions the effect of any mixture of the Illinois River water with the Missouri River water at the intake tower of the St. Louis waterworks would, therefore, tend to diminish the colon content of the water at that point, thereby rendering it less dangerous for human use. Such mixing of the Illinois and Missouri waters as took place would hence improve the conditions existing during this period in the Mississippi River at the intake tower.

"Throughout this period, in the latter part of 1901, the water was low in the three rivers, the Illinois, the Mississippi and the Missouri.

"The exact figures of the height of the water are given in the detailed tables embodying the colony counts already submitted. (6132.)

"Q. Professor, Mr. Allen Hazen, on page 4530 of the record, was asked this question, 'when the mixing begins at the mouth of the Illinois River, by the time it gets to the mouth of the Missouri River, is that mixing complete?' and he answered, 'I do not think it is absolutely complete. It is approximately so; more so at low water than at high water.' What do your bacterial analyses show as to whether there is more mixing of these waters at low water than at high water?

"A. I may state in reply that, in my opinion, the total number of bacteria in the water at the intake tower and near the Missouri shore at the Chain of Rocks, as well as the number of colon bacteria in the water at these points, shows conclusively that during this period of low water the water collected at these two stations was almost wholly, if not altogether, Missouri River water and was mixed little, if any, with the water from the Illinois. If it be true, therefore, that mixing is more complete at low water than at high water, it will certainly follow that the amount of Illinois River water present in the Mississippi at these two points at high water stages must be exceedingly small. (6132, 6133.)

"Q. Professor, from your survey of the Missouri and Illinois rivers, as evidenced by your various analyses heretofore testified to in this case, will you state how the Missouri River compares with the Illinois River before the 17th day of January, 1900, as to its sanitary quality

"A. *During this period the condition of the Missouri River, as compared with that of the Illinois River above Grafton, was less satisfactory from the sanitary point of view, and was distinctly inferior to the Illinois River at Averyville.*

"Q. How did the Illinois River compare with the Missouri River after January 17, 1900?

"A. The relative character of the two rivers was not materially different from the 17th of January, 1900, to the 1st of July, 1900. That is to say, the Missouri River water was more objectionable from a sanitary standpoint than the water of the Illinois River at its mouth or at Averyville.

"How did the Illinois River compare with the Missouri River for the period 1901?

"A. *During the period October-December*, 1901, *when daily examinations were made and a large number of results obtained, the sanitary quality of the Missouri River water was, in my opinion, distinctly inferior to the Illinois River water at its mouth and at Averyville, as shown especially by the colon determinations.*" (6137-6138.)

Professor Burrill, of the University of Illinois, who made the bacterial examination, in conjunction with Professor Palmer, who made the chemical examination, after he had introduced his tables and plates of illustration for 1899, was asked this question:

"Q. What do these plates indicate as to the comparative condition of the waters of the Illinois River at Grafton, the Mississippi River above Grafton, and the Missouri River just above its mouth, at the place called West Alton?

"A. There is practically no difference so far as shown by these plates, in the waters of the Illinois River before they enter the Mississippi River at Grafton, and of the Mississippi River above the mouth of the Illinois River at this place. There is, however, a continuous exhibit of a greater number of bacteria in the waters of the Missouri River at West Alton than there are in either the Illinois River or the Mississippi River at Grafton.

"Q. What conclusion do you draw from this difference?

"A. I can only infer that the waters of the Missouri River at West Alton have in them greater contamination than have the waters of the Illinois River and the Mississippi River at Grafton. I do not think I have enough information of the special reasons for the conditions as shown for the waters of the Missouri River at West Alton to be able to say the pollution is greater there than in the Illinois and Mississippi at Grafton." (5749.)

Again, in his coli determination upon the waters of the Illinois and Mississippi and Missouri rivers, on page 5756, he states:

"If, now, we compare the results obtained from the waters at the mouth of the Illinois River with those in a similar way from the waters of the Mississippi River above the mouth of the Illinois and of the Missouri at West Alton, we shall have the following exhibit:

"In the Illinois River, 31 positive, 23 negative, and 1 questionable result. In the Mississippi River water, 35 positive, 20 negative, 1 questionable result; from the waters of the Mis-

souri River, 36 positive, 7 negative and 7 questionable results.

"This indicates that the organism is most often present in the waters of the Missouri River; next in those of the Illinois at the mouth, and somewhat less frequently in those of the Mississippi, if we take into consideration the whole time of the investigation.

"By reference to the graphical showing in this connection it will be seen that the less number of positive results through the whole course of the stream from Bridgeport to Mitchell was at Averyville, there being a slightly greater percentage of positive results at Grafton than at this last place. The greater number shown for the waters collected near Mitchell seem to be due to the larger proportion or greater number in the waters of the Missouri River. (5756.)

"Q. Based upon your bacterial examinations of the waters in the Illinois River and its tributaries, and of the Mississippi River and the Missouri River, to which you have referred and which are embraced in the tables and plates which have been submitted in evidence by you, what is your opinion as to the effect produced, if any, upon the waters of the Mississippi River below the mouth of the Illinois River by the opening of the Chicago Drainage Canal in January, 1900?

"A. In my opinion, the very decided reduction of the number of the bacteria found in the course of the stream up to the time the waters reached Averyville, causing the waters at this place to assume the character of a normal river, indicates that the contaminations from the sewage introduced into the stream from Chicago have disappeared at this point, and I cannot otherwise than conclude that the evidence now presented shows that the water at the mouth of the Illinois River at Grafton is practically free from any such contaminations introduced at Chicago.

"I find, also, that the contamination as indicated in the water at the inlet tower at the Chain of Rocks has a larger portion of its contamination from the water of the Missouri River rather than from the combined waters of the Illinois and the

Mississippi at this point. I can say that the opening of the Drainage Canal has had no effect upon the waters of the Mississippi River one way or the other.

"Q. Professor, did you make any bacterial examinations of the waters of the Illinois River, the Mississippi River and the Missouri River in the months of October, November and December, 1901?

"A. I did.

"Q. Under what circumstances were those samples taken?

"A. They were taken in the same manner and by the same arrangement that the samples were taken in the years 1899 and 1900." (5758.)

"These tables were prepared by me, and are intended to indicate the number of bacteria in a cubic centimeter, and the identifications of the bacillus coli communis in the weekly samples taken from the Illinois River at Averyville, at Pekin, at Grafton and from the Mississippi River above the mouth of the Illinois at Grafton, and from the Chain of Rocks, in the Mississippi River, and from the Missouri River at Fort Bellefontaine." (5760.)

Tables of these determinations are found on pages 5761 to 5769.

"Q. State whether you computed any averages in reference to these tables, and if so what these averages show?

"A. The averages were computed from the total tests made from the waters collected at each place, and also the percentage of positive results from all tests made for bacillus coli communis were made from the waters in each place.

"Q. Now, what do those show in each of the tables?

"A. The average number of bacteria shown for Averyville in this examination from October 16th to December 30th is 13,691, and the percentage of positive tests for the bacillus coli communis is 6.2.

"The average number of bacteria from the Illinois River at Pekin for the time mentioned is 299,000, and the percentage of positive tests for the bacillus coli communis is 76.

"The average number of bacteria from the Illinois River at Grafton is 8,441 and the percentage of positive results for the tests for the coli communis is at this place 10.7.

"Of the waters of the Mississippi River above the mouth of the Illinois at Grafton the average number is 5,407, and the percentage of positive results in the tests for bacillus coli communis is 11.5.

"I may state there were four places of collection from the Chain of Rocks in a cross-section of the river. Those taken from near the Illinois shore averaged 52,177, and the positive results for the bacillus coli communis tests was 21.7 per cent.

"Those taken from midstream averaged 43,185, and the positive results for the tests for bacillus coli communis is 50 per cent.

"Those taken near the intake tower, the average number was 127,862, and the number of positive tests for bacillus coli communis is 36.3.

"The average number of bacteria from the water taken near the Missouri shore amounted to 32,845, and the positive results of the tests for bacillus coli communis shows 57 per cent. of the total number of tests.

"Now, the general average for all tests at this point was 63,402 bacteria per cubic centimeter, and the positive tests for bacillus coli communis is 41.1 per cent.

"From the waters of the Missouri River at Bellefontaine the average number of bacteria was 127,353, and the positive results for tests for bacillus coli communis is 57.1 per cent. (5770.)

"Q. Now, please state, professor, what significance you attach to the colony counts and the presence of the bacillus coli communis as they appear in the tables which you put in evidence, and also as graphically illustrated by the plate just put in evidence.

"A. This series of investigations shows very closely just what was presented in the series for 1899 and 1900, already presented, and gives clear evidence that the water from the

stream at Averyville is comparatively pure, or at least free from great numbers of micro-organisms, and also quite commonly free from the bacillus coli communis. The percentages of total tests which were positive in this examination proved to be 6.2.

* * * * * *

"If we compare the results from the waters of the Illinois River near its mouth with that of the Mississippi River above the mouth of the Illinois, we find the result in regard to the number of colony counts slightly in favor of the Mississippi River, as was found in the previous case, the average here being 5,407. This difference between 5,407 and 8,441 may or may not show a constant condition of things, as the difference is too small for this purpose, but the tests in regard to these two waters made for the determination of bacillus coli communis favor somewhat the Illinois River water as against the Mississippi River water, since the percentage in the former is 10.7 and in the latter 11.5.

"At the Chain of Rocks, where four samples were each time taken across the stream, the indications are that the pollution increases from the Illinois shore to the Missouri shore, as this series of counts show, namely, for the Illinois shore 52,177, for the midstream 43,185, for the intake tower 127,862 and for the Missouri shore 32,845. This last is the only count which does not support the statement just made.

"For the determination of bacillus coli communis in the same water, we find, beginning with the sample taken near the Illinois shore, 21.7 per cent.; from midstream, 50 per cent.; from the intake tower, 36.3 per cent., and from the Missouri shore, 57 per cent.

"Comparing now these last results with those obtained from the waters of the Missouri River at Bellefontaine, or, as it is sometimes called, West Alton, the indications are that this latter stream is considerably more contaminated, since the average number of bacteria per cubic centimeter is 127,353, and the percentage of positive tests for bacillus coli communis is 57.1.

"This means, so far as this evidence can be taken to mean anything, that the waters at the intake tower are largely derived from those of the Missouri River, and to present this a little more clearly, the results of the examinations of the water from the Missouri at Bellefontaine and of those at the intake tower may be placed together. From the former, that is, the Missouri, the average number of bacteria per cubic centimeter is 127,353; at the intake tower the average is 127,862. The percentage of positive tests for bacillus coli communis from the Missouri River is 57.1 per cent., and the intake tower is 36.3 per cent.

"The whole examination seems to indicate that the water, which is comparatively pure at Averyville, becomes very greatly contaminated at Pekin, clears up again at Grafton, and at this point compares favorably with the waters of the Mississippi River above the mouth of the Illinois, and very favorably with those of the Missouri at Bellefontaine." (5773-74.)

Confirmatory of the conclusions arrived at from the analyses by Professors Jordan and Burrill, as to the relative pollution of the Illinois, Mississippi and Missouri Rivers, wherein the Missouri shows greater pollution and contamination than does the Illinois or Mississippi, the testimony of Professor Long upon this proposition is worthy of consideration and reproduction.

The tables of his analytical results for 1901, for the Illinois, Mississippi and Missouri Rivers, with the table of averages, are found on pages 4230 to 4239 of the printed record; and his testimony giving his conclusions is set out as follows:

"Mr. Todd: Professor, from this table of averages, what conclusions do you draw as to the relative pollutions of the Illinois River above Grafton, the Mississippi River above Grafton and the Missouri River 600 feet above its mouth?

"A. From a consideration of these tables, I draw the following general conclusion:

"That the organic condition of the Illinois River above Grafton is very much better than the organic condition of the Mis-

souri River above its mouth. This is shown by several factors. By the factor measuring the oxygen absorption, which for the Illinois River or for the unfiltered water, 4.31 parts per million, and for the filtered water 3.21 parts per million. For the Missouri, for the unfiltered water, 10.28 parts per million, and for the filtered 3.17 parts per million.

"By the factor for the albuminoid ammonia, as measuring the substances of comparatively complex composition to be yet decomposed, 0.413 parts per million in the Illinois as against .6 parts per million in the Missouri.

"By the factor measuring the organic ammonia, as determined by the Kjeldahl process, which is .81 parts per million for the Illinois, as compared with 1.61 parts per million for the Missouri.

"As measured by the oxygen absorption, the Illinois River contains less organic matter above its mouth than does the Mississippi River. (4239.)

"As measured by the albuminoid ammonia, the Illinois River contains very nearly the amount of organic matter that is contained in the Mississippi River.

"As measured by the organic ammonia determined by the Kjeldahl process, the amount in the Illinois River is not greatly different from that in the Mississippi River.

"Considering the chemical reactions due to the living organic matter in the Illinois and the Missouri Rivers, it is evident that the condition of the Illinois is very greatly superior to that of the Missouri, throughout the whole period. This is especially shown by the chemical determinations made to indicate the presence of those living organisms which decompose protein matters, with the production in indol. The reaction for indol is found at the mouth of the Illinois River above Grafton very rarely, while in the Missouri River, 600 feet above its mouth, this reaction is extremely common, showing a very much greater number of the living organisms capable of bringing about this peculiar chemical decomposition in the Missouri River than are found in the Illinois River.

"From the information obtained from the tests for the presence of those organisms, which have the power of breaking down carbo-hydrates, with the liberation of acid, which subsequently coagulates milk, it is likewise evident that the contamination in the Missouri River is very much greater than the contamination in the Illinois River through the same period. The number of acid forming organisms as disclosed by the results of the tests being greater in the Missouri than in the Illinois.

"It also appears by a comparison of the tables in which a determination of the number of living organisms was made by the so-called colony count process, that the Missouri River shows a greater contamination than does the Illinois, through this same period. In its organic condition, as indicated by these chemical tests, which I have described as sometimes called bacterial, although they involve true chemical reactions, the Illinois River is as pure as the Mississippi at the point of junction of the Illinois with the Mississippi, and *the Illinois River is very much purer than the Missouri at the point where the Missouri flows into the Mississippi.*

"When we turn to these results just given, as applied to a comparison of the results for the fall of 1901, and when we turn to the results obtained in the spring of 1902, the same general conclusions follow. The indol reaction is more common in the Missouri River than it is in the Illinois.

"The purely chemical tests indicate the presence of a larger amount of organic matter in the Missouri River than is indicated in the Illinois.

"Q. From your chemical analyses, is the Illinois River during the period that this investigation was made a more or less polluted stream than the Missouri for the same period?

"A. *It is, beyond question, true that at the period of this investigation the Illinois River at its mouth was a much less contaminated stream than the Missouri River at its mouth.*

"Q. How did the Missouri River compare with the Mississippi River at the points where this investigation was made?

"A. As disclosed by the experiments described, the Mis-

souri River is far more contaminated organically than the Mississippi at the points at which the samples analyzed were taken." (4239 to 4241, inclusive.)

"Q. Since the opening of the Drainage Canal, what has been the effect of the turning of the waters of Lake Michigan through the Drainage Canal into the Illinois River, upon the sanitary quality of the water in the Illinois River?

"A. Because of the addition of a large volume of Lake Michigan water to the canal water flowing down the Illinois, and because, further, the increase in the amount of pure water is very much in excess of the increase in the amount of sewage carried at the same time, the resultant effect is produced that the mouth of the Illinois River to-day is in a far better sanitary condition than obtained before the Drainage Canal opened.

"Q. Taking into consideration all the knowledge that you have upon the question of the quality of the water of the Illinois River, has the sanitary condition of the water of the Illinois River been improved or damaged by the opening of the Drainage Canal?

"A. Taking into consideration all the conditions which have have been supposed, and especially the condition of the increased pollution, I am still of the opinion that the sanitary condition of the water of the Illinois River at its mouth has been improved instead of injured by the increased flow through the Drainage Canal.

"Mr. Todd: Since the opening of the Drainage Canal, what is your opinion as to whether the waters of the Illinois River are more or less sanitary than the waters of the Missouri or the Mississippi Rivers?

"A. *Beyond all possible question, the sanitary condition of the Illinois River at its mouth is far superior to the Missouri River at its mouth*, and not greatly different from the condition of the Mississippi River at a point where the Illinois and Mississippi Rivers unite.

"Q. What effect does the sewage discharged through the Drainage Canal have upon the waters of the Mississippi River and the Missouri River at the Chain of Rocks?

"A. As I have not made any analyses at the Chain of Rocks, the question ought to apply to some other point.

"Q. Changing from the Chain of Rocks to the point where the Missouri and Mississippi Rivers mingle, at the mouth of the Missouri?

"A. As I have stated in my previous testimony, I believe the effect of the Chicago sewage is completely lost before the mouth of the Illinois River is reached, and therefore cannot be a factor in determining any pollution in the Mississippi or Missouri Rivers.

"Q. Assume that the waters of the Illinois River in 1902 were emptied directly into the Missouri River at its mouth, before the Missouri River enters the Mississippi, or before the Illinois empties into the Mississippi, would the waters of the Illinois River pollute the waters of the Missouri River?

"A. No. *On the contrary, the water of the Missouri will contaminate the water of the Illinois, the water of the Illinois being in a purer and better sanitary condition at that time than the water of the Missouri.*" (4254 to 4256.)

Professor Robert F. Zeit, who made the bacterial examination of the waters of the Mississippi, Illinois and Missouri Rivers, testified as to the comparative pollution of the three rivers as follows:

"Q. From the table which you have read in evidence in this case already, state what conclusions you draw as a bacteriologist, pathologist and biologist as to the relative bacterial purity of the waters of the respective streams, at the points indicated in these examinations to which you have testified during the latter part of the year 1901 and the first part of the year 1902.

"A. In regard to the bacteriologic flora of the three rivers at that time, from the investigations made as a bacteriologist, I would judge that the Missouri was more polluted than either the Mississippi or the Illinois during the periods of these examinations, and that the Mississippi was more polluted than the Illinois at the same time.

"Q. Would your conclusion, which you have just stated, which was based on certain bacterial examinations made by you and to which you have testified, be changed in any way by a consideration of the question of the amount of sewage that may have been deposited in any of these streams at any point above the places at which you made your investigation?

"A. This investigation is entirely independent of any other data. It is simply to determine, if the water of these three rivers, specimens of which were examined, is to be condemned bacteriologically, and which of the three is more dangerous than the other two, and I think bacteriologically and qualitatively that can be determined a great deal better in this way than by a great many of the methods that are employed sometimes as the more dependable methods by sanitarians. A physically pure water that contains a great number of pathogenic bacteria is certainly to be condemned. A water may be physically bad and contain a thousand times the number of bacteria that the other water contained, and yet it may not contain any pathogenic bacteria. In spite of its apparent bad character physically, it need not be condemned. I would be perfectly willing to swallow water in which I was capable of producing a culture, like I have done here, and keep it twenty-four hours in the incubator, and inject it intra-peritoneally into the abdominal cavity of a guinea pig without any effect. After all, the question of determining the safety of drinking water from a river or a lake does not depend upon its physical character and the number of bacteria that may be present, but depends upon the number and kind of pathogenic bacteria present in the water. I testified as a medical bacteriologist, and I believe my opinion in this matter has some cause and some justice." (4460.)

And again he testified as follows:

"Mr. Todd: From your bacteriological examinations of the water of the Illinois, Mississippi and Missouri Rivers as represented by the tables you have submitted, which one of these three rivers from your examinations discloses the least amount of impurities as manifested and evidenced by your bactriological tests?

"A. From thirty-eight specimens of the Illinois River and thirty-seven from the Mississippi River, and thirty-six from the Missouri River, made during the months of October, November and December, 1901, and February and March, 1902, I concluded *that bacteriologically the Illinois River was less polluted than either the Mississippi or Missouri.*

"Q. If the Illinois River discloses the least amount of impurities, what would be the effect of the Illinois River emptying into the Mississippi River at Grafton and subsequently uniting with the Missouri River at its mouth, upon the combined waters of the Mississippi and Missouri Rivers at the intake tower at the Chain of Rocks, and does the mixing of the Illinois River with the Mississippi and the Missouri Rivers, as indicated, add any danger to the already polluted waters of the Missouri and Mississippi Rivers?

"A. I can only judge from the results of these tables, and if such a condition would exist and would have existed during this time, *it would only have tended to make the Missouri less infectious to add the water of the Illinois to it*, because the Illinois River was less infected than either the Mississippi or the Missouri. So during those times I would say that *there would have been no source of danger to add the Illinois to the already severely polluted Mississippi or Missouri.*" (4474.)

Mr. John W. Hill, of Philadelphia, testified in regard to the comparative pollutions of the three rivers, and a part of his testimony is herewith submitted:

"Q. What is your opinion as a sanitary expert, based upon your examination of the tables introduced in evidence by Professors Long, Palmer, Burrill and Jordan, of the waters of the Illinois, Mississippi and Missouri Rivers, as represented by such tables which you have examined, as to which of these three rivers from these analyses discloses the least amount of impurity or pollution?

"A. Basing an opinion upon the technical data in the volume entitled 'Streams Examination', previously referred to in my testimony, *I should regard the quality of the water of the*

Illinois River at Grafton as no worse and in some respects better than the mixed waters of the Illinois, Mississippi and Missouri Rivers at the point in the Mississippi River, below Grafton, as shown by the data in the tables of technical data previously offered as a part of my testimony.

"Q. How does the Missouri River at Fort Bellefontaine or West Alton compare with the Mississippi River above Grafton and the Illinois River at Grafton?

"A. *From a bacteriologic point of view, the water of the Illinois River at Grafton is decidedly better than the water of the Missouri River at West Alton. Considering the suspended matter, the water of the Illinois River at Grafton is superior to the water of the Missouri River at West Alton.*

"The same statement may be made with reference to total solids.

"The same statement may be made with reference to the nitrates and nitrites; the degree of nitrification being shown as greater for station 21 at Grafton, at the mouth of the Illinois River, than for station 32, West Alton, on the Missouri River.

"Considering the chlorine alone, the water of the Illinois River at Grafton would not be considered as good as that of the Missouri River at West Alton.

"Q. If the Illinois River discloses a less amount of impurities than the Missouri, what would be the effect of the water of the Illinois emptying into the Mississippi River at Grafton and subsequently uniting with the Missouri at its mouth upon the combined waters of the Mississippi and Missouri Rivers at the intake tower at the Chain of Rocks?

"A. Considering the relatively small natural stream flow from the watershed of the Illinois River, when compared with the stream flow of the Mississippi River above St. Louis and the stream flow of the Missouri River and ignoring or setting aside the fact of the water of the Illinois River being either better or worse than that of the two larger streams, the addition of the ordinary stream flow from the Illinois River to the combined stream flow of the other two rivers would not have

much effect either way. In order to reduce this to a more definite statement, I have prepared a table showing the relative area of the drainage basins of the three rivers mentioned in the question, and assuming for the present that the mean rainfall would be the same over the combined drainage area of the Illinois, Mississippi and Missouri Rivers upon this basis, and omitting all flow of Chicago sewage or of water from Lake Michigan, *of each* 100 *gallons of water flowing in the Mississippi River opposite the Chain of Rocks,* 75¼ *would come from the Missouri River watershed,* 20⅓ *from the Mississippi River watershed and the remaining* 4.4 *from the Illinois watershed.*

"As a matter of fact, however, the mean rainfall over the whole area of the Missouri watershed is not so great as that over the watershed of the Illinois and of the Mississippi Rivers, and it is probable that of the total flow of water in the Mississippi River opposite St. Louis 70 per cent. can be charged or credited to the Missouri River watershed, 20 or 22 per cent. to the Mississippi watershed and the remaining 6 or 7 per cent. to the Illinois River watershed. In this case it is assumed that no water falls in the Illinois River except that due to the rainfall on its drainage basin.

"Q. Have you figured out the results, adding the flow from the Drainage Canal?

"A. I have, upon the assumption only that the mean annual rainfall is substantially uniform over the entire Mississippi River basin embraced in the watershed of the Illinois and Mississippi Rivers above St. Louis and the Missouri River, which is not as stated in the answer to the previous question, quite true, but for this purpose may be accepted as true. Allowing the least stream flow of the Illinois River at Grafton, as reported by the United States engineers in October, 1891, of 1,000 cubic feet per second, and assuming the discharge from Lake Michigan through the Drainage Canal of 300,000 cubic feet per minute, or 5,000 cubic feet per second, and allowing for the discharge of sewage based upon 90 per cent. of 85 per cent. of the total water consumption

of Chicago, which produces a discharge of 424 cubic feet per second, the percentage of volume flow with the least recorded stream flow of the Illinois River at Grafton would be seven (7). *Taking this flow into consideration, and also taking into consideration the flow of sewage from Chicago plus the flow from Lake Michigan, of the water flowing in the Mississippi River opposite St. Louis, 20 per cent. would be credited to the Mississippi River, 75½ per cent. to the Missouri River and 2.96 per cent. to the Illinois River, and* 1.54 *to the influence of the discharge of the Chicago sewage, or such water as is carried with the sewage into the Drainage Canal, exclusive of the diluting water drawn from the lake.*" (7541 to 7544.)

Professor E. G. Smith, of Beloit, who made a careful study of the analytical tables, as given in "Streams Examination", testified as follows:

"Q. What is your opinion, as a sanitary expert, based upon your examination of the tables of analysis introduced into evidence by Professors Long, Palmer, Burrill and Jordan, of the waters of the Illinois River, the Mississippi River and the Missouri River, as represented by such tables as you have examined as to which one of these three rivers from this analysis discloses the least amount of impurity or pollution?

"A. By comparison of the data submitted by Professors Long, Palmer, Burrill and Jordan, *it is my opinion that the Illinois River at Grafton discloses the least amount of impurity or pollution of the three rivers, the Illinois, Mississippi or the Missouri.*

"Q. If the Illinois River discloses from such data as aforesaid the least amount of impurities, what would be the effect of the waters of the Illinois River emptying into the Mississippi River at Grafton and subsequently uniting with the Missouri River at its mouth, upon the combined waters of the Mississippi and Missouri Rivers at the intake at the Chain of Rocks?

"A. It would be evident that if the Illinois River is of a better quality, or does not show as much impurity as either of

the other rivers, it would really benefit them, if anything, and in proportion as the waters became mixed. If the evidence should be that the Illinois River practically hugs the east shore and does not mix, particularly , it would not affect them. If, on the other hand, the data should show that there is a gradual mixing, then in proportion as this mixing occurred to that degree it would improve, if anything. The differences are not very great, however, between the data as I have examined them." (6774.)

"From a study of these tables, these tables being the results of the investigations of the samples of water on these different dates of the Illinois River at Grafton and the Mississippi River at Grafton, I am of the opinion that so far as numbers of bacteria are concerned, the waters of the Illinois River at Grafton are of a better quality than the waters of the Mississippi River at Grafton." (6806.)

He also made a compilation of the tables submitted by Professor Jordan, in the report of "Streams Examination," which compilation appears on page 6809.

He states: "From a comparison of the data submitted in this table, representing the bacterial flow of the Illinois River at Grafton with the flow of the Mississippi River at the same point, and points below, as given in the table submitted by Professor Jordan in the report of "Streams Examination," I find from the average of the counts of the bacteria for the first four months of 1900, which months, according to my study of the tables, represent the rivers in their worst condition, it is my opinion that the Illinois River, as indicated by these tables, is better in the number of bacteria contained in the same than the Mississippi River at Grafton or the Mississippi River at Alton, 100 feet from the Illinois River, or at the Mississippi River at Alton, one-quarter distance from the Illinois shore, or the Mississippi River at Alton, in midstream, or the Mississippi River one-quarter distance from the Missouri shore, or the Mississippi River at Alton, 100 feet from the Missouri shore, or the Mississippi River at the Chain of

Rocks, 400 feet from the Illinois shore, or the Mississippi River at the Chain of Rocks in midstream, the Mississippi River at the Chain of Rocks at the intake tower, the Mississippi River at the Chain of Rocks, 400 feet from the Missouri shore, and from Bellefontaine, West Alton, Missouri.

"This table indicates the much larger number of bacteria at these points than from the Illinois River at Grafton, this covering, as already stated, the first four months of 1900, taken from the tables; the river appears to be in its worst condition during the period which the table covers." (6810.)

Professor W. P. Mason considered this question of comparative pollution of the three rivers, as evidenced by the colon determinations of Professor Jordan for 1901, and prepared a chart to graphically illustrate the data which he selected, which appears on page 6933 of the record, and interpreted the chart as follows:

"From an examination of this chart, I observe that the bacillus coli communis is more frequently found in the waters of the Mississippi River at Grafton, the Illinois at Averyville, the Missouri at Bellefontaine, and the Mississippi at the St. Louis intake, and the Illinois at Pekin, than it is in the Illinois at Grafton, operating upon 1 c. c. of water. Operating upon the same quantity of water, I observe that the Mississippi River at the Chain of Rocks contains the bacillus coli communis most frequently upon the Missouri shore, next in frequency at the intake tower, next in frequency in midstream, and least in frequency on the Illinois shore.

"Judging from the bacillus coli communis contents of the several waters, operating upon 1 c. c. as stated, the relative purity of the waters in question would stand, *first in purity, Illinois River at Grafton;* (2) Mississippi River at Grafton; (3) Illinois River at Averyville; (4) Missouri River at Bellefontaine; (5) Mississippi River water at the St. Louis intake, and (6) the Illinois River at Pekin. Basing upon the same data from the several waters taken at the Chain of Rocks, the relative degrees of purity would stand, *most pure water from*

the Illinois shore, next in purity from the midstream, next in purity from the intake tower, and least in purity from the Missouri shore.

"Q. How does the Missouri River at Bellefontaine and the Mississippi River at Grafton and the Illinois River at Grafton compare as to purity or pollution?

"A. Basing my reply upon the bacillus coli communis contents, they compare as follows:

"*The Illinois River at Grafton is the most pure.*

"The Mississippi River at Grafton is next, and the Missouri River at Bellefontaine is the least pure." (6935, 6936.)

Professor Leonard P. Kinnicutt, who examined the analytical charts and tables which appear in the book known as "Streams Examination," also testified in regard to the comparative pollution of the three streams as follows:

"Q. What is your opinion as a sanitary expert, based upon your examinations of the tables of analyses introduced in evidence by Professors Long, Palmer, Burrill and Jordan, of the waters of the Illinois, Mississippi and Missouri Rivers, as represented by such tables as you have examined, as to which one of those three rivers, from those analyses, discloses the least amount of impurity or pollution?

"A. From the chemical and bacterial analyses introduced in evidence by Professors Long, Palmer, Burrill and Jordan, together with my study of the tables and charts that I have prepared and introduced as evidence, it is my opinion that the Mississippi and the Illinois Rivers practically contain about the same amount of impurity, *while the Missouri River contains a larger amount of impurity than either of the other two rivers named.*

"Q. If the Illinois River discloses from such data as aforesaid a less amount of impurity than the Missouri, what would be the effect of the waters of the Illinois River emptying into the Mississippi River at Grafton and subsequently uniting with the Missouri River at its mouth, upon the combined waters of the Mississippi and the Missouri Rivers at the intake at the Chain of Rocks?

"A. *The effect under the conditions stated would be one of purification upon the combined waters of the Mississippi and the Missouri Rivers, and would render those waters less harmful.*

"Q. Does the mixing of the Illinois with the Mississippi and the Missouri Rivers, as indicated in the foregoing question, create any added danger, or pollute or contaminate the waters of the Missouri and Mississippi Rivers, at Grafton?

"A. It does not." (7459 and 7460.)

Mr. Rudolph Hering, in studying the relative infections or pollutions of the Illinois, Mississippi and Missouri Rivers at St. Louis, made a comparison between the three rivers at St. Louis, based upon the length of life of the typhoid bacillus as fixed by an experiment made under the direction of Hiram F. Mills; and, assuming the results of that experiment to be compatible with the results as they obtained in the Illinois, Mississippi and Missouri Rivers, he prepared a chart and introduced the same in evidence in this case, which chart appears on page 7001 of the printed record.

His testimony upon this point is worthy of consideration in view of the fact that the complainant in this case does not appear to understand the purport of this chart, or else, understanding, failed entirely to use the conclusions for the purposes for which they were drawn.

Reference to the testimony of Mr. Alvord, and the chart which he prepared (7782), shows conclusively that Mr. Alvord hopelessly failed to understand the object of Mr. Hering's chart, for the reason that he drew a chart as applicable to the Illinois River alone, without reference to the Mississippi and Missouri Rivers, whereas Mr. Hering's chart would be meaningless unless it were for the purpose of comparing the relative pollutions of the three rivers in question.

Mr. Crane, who prepared this chart under the direction of Mr. Hering, testifies in regard to the sources from which he got the information for the chart as well as the manner of preparing the same. He states:

"The curves were obtained by using the data obtained by the Massachusetts State Board of Health and published in a report of the State Board of Health of Massachusetts, in a paper by Hiram F. Mills, entitled 'Typhoid Fever in Its Relation to Water Supply.'

"The results there given were embodied in a curve, and from this curve I deduce the following:

"100 per cent of the bacteria were living on the first day.
" 73.4 per cent. on the third day.
" 50.8 per cent. on the fifth.
" 30.8 per cent. on the seventh.
" 14.1 per cent. on the ninth.
" 5.2 per cent. on the eleventh.
" 2.5 per cent. on the thirteenth.
" 1.6 per cent on the fifteenth.
" 1.0 per cent on the seventeenth, and
" 0.4 per cent. on the nineteenth.

"Assuming that the number of typhoid bacilli contributed was proportional to the population, the curves were started at the extreme from St. Louis. Working towards St. Louis, the results for the first, third, fifth, etc., days were plotted. These curves were plotted for each city in turn.

"The results at St. Louis were so arranged that the result for the Illinois River was placed opposite the combined results of the Missouri and Mississippi Rivers, so that they might be directly compared." (7013.)

Mr. Hering, in explaining the chart above referred to, states:

"The chart contains two diagrams. The lower one exhibits the profiles of the Missouri, Mississippi and Illinois Rivers above St. Louis.

"The upper line indicates the Missouri River as far as Omaha.

"The next line the Mississippi River as far as Minneapolis, and the third line the Illinois River as far as the City of Chicago.

"The three profiles are plotted relative to their elevations and to their distances above St. Louis.

"It will be seen from these profiles that the Missouri River is the steepest of the three, that it falls from Omaha at an elevation of 960 to St. Louis at an elevation of about 380 above sea level.

"The Mississippi River falls from Minneapolis at an elevation of 794 feet to the elevation above mentioned at St. Louis. The Illinois River and Sanitary District Canal fall from an elevation of Lake Michigan, which is about 578, to Grafton, where it enters the Mississippi River. The elevation at Grafton is slightly over 400 feet above seal level.

"The distance of Omaha and Minneapolis to St. Louis by water is about 680 miles.

"The distance from Lake Michigan to St. Louis by water is about 400 miles.

"It will be seen that the Missouri River is the steepest one and the velocity of the water in the river is the greatest. The Mississippi River is less steep and the velocity would be less great. Therefore, it will take the water longer to flow from Minneapolis to St. Louis than from Omaha to St. Louis, although the distance is nearly the same.

"The Illinois River is the flattest of the three rivers and the water has a less rapid velocity.

"The upper diagram on the chart exhibits certain deductions made on the basis indicated in the title with reference to the longevity of the typhoid bacillus as found by Mr. Hiram F. Mills. In the above mentioned report it is stated, 'To prove whether typhoid fever germs would survive in the Merrimac River water, when at the low temperature of the month of November, long enough to pass from the Lowell sewers to the service pipes in Lawrence, a series of experiments was made by the Board by inoculating water from the service pipe with typhoid fever germs and keeping the water in a bottle surrounded by ice at as near freezing as practicable for a month, and each day taking out 1 c. c. and determining the number of typhoid

fever germs. The number continually decreased, but some survived twenty-four days. * * *

"The ordinates of the curves presented on the diagram represent the relative number of typhoid bacilli still living at towns indicated in terms of population of such towns, it being assumed, in the absence of other information at hand, that the number of germs is directly proportioned to the population.

"From an inspection of the diagram, it will appear that Chicago is situated, so far as the average flow of water is concerned, about 18½ days from St. Louis. Kansas City, on the Missouri, on the same basis, is situated about 6¾ days, and Omaha about 11.6 days from St. Louis.

"On the Mississippi River, Minneapolis and St. Paul are situated about 15 days from St. Louis on the same basis. The other cities indicated are at shorter distances.

"The conclusions of the chart, as indicated by the ordinate at St. Louis, are that the relative proportion of typhoid bacilli arriving at St. Louis from the populations situated on the Illinois, the Misouri and the Mississippi Rivers, between the limits of Chicago, Omaha and Minneapolis, are about as 13 to 96 to 107, respectively. These figures are merely the proportions. They indicate the relative frequency of the still virulent typhoid bacilli at St. Louis, arriving there from various cities on these three rivers, based on the population of the cities, and also based on the examinations made by Hiram F. Mills as to the longevity of the typhoid bacilli." (7002 to 7003.)

And again, Mr. Albert S. Crane testified, in reply to this question: "What does the variation between the Illinois, the Mississippi River and the Missouri River, as indicated upon this chart, represent as to the comparative populations at St. Louis of these three rivers?

"A. This would show that the Illinois River has the effect of a city of 13,000 situated immediately above St. Louis, the Missouri River of a city of 96,000, and the Mississippi River of a city of 107,000.

"Q. Or a relationship of 13 to 96 and 107?

"A. Yes, sir." (7013.)

And again, Mr. Crane states on page 7018, in response to the question: "If at maximum flood time the distance in time from Kansas City was three days instead of 6.8, as shown by this chart, what would it show?

"A. 230,000. That is, the effect of the cities on the Missouri River would be that of a city of 230,000 directly above St. Louis."

From this chart and the testimony introduced in evidence by Mr. Hering, based upon the experiment of Hiram F. Mills, as applied to the three rivers, with the conditions obtaining in those rivers as they do to-day, and upon the assumption that the mortality of typhoid germs, as disclosed by that experiment, kept at almost a freezing point, is comparable to the conditions as they exist in the Illinois River—the conclusion of that chart as to the comparative population of the three rivers is expressed in the ratio of 13 to 96 to 107, whether that means, population, amount of sewage, amount of infection, or amount of pollution; and it does not mean that under the present conditions there is situated immediately above St. Louis a city with a population of 13,000 people sewering into the Mississippi River on the Illinois side, or a city with a population of 96,000 people situated upon the Mississippi River, or a city of 107,000 people situated at the mouth of the Missouri River, but it merely means, as Mr. Hering testified in this case, a relative infection at St. Louis derived from the three rivers under investigation, based upon the result of this experiment as applied to these rivers.

This experiment was the best information upon the subject that Mr. Rudolph Hering had at the time he constructed the chart. In his testimony, as bearing upon that point, defendants desire to quote the following answer made by Mr. Hering upon cross-examination, wherein he says:

"When I entered into the study of this case, the best information that I was familiar with regarding the longevity of the typhoid bacillus, which is the most important one to con-

sider in cases of this kind, was that contained in the reports of the Massachusetts State Board of Health and which I used in preparing the chart entitled 'Sanitary District of Chicago: schematic representation of the self-purification of the waters of the Missouri, Mississippi and Illinois Rivers between the cities indicated,' etc.

"Since having been engaged on the case, I have become acquainted with similar investigations which have recently been made by witnesses in this case, which information is much more exact and practicable and in accordance with actual facts, in my opinion, than the Massachusetts experiments. Had I asked this diagram or this chart to be prepared later I should have used the *later* and *better* information contained in the recent testimony in this case." (7027.)

And as the evidence which has already been discussed in this brief upon the longevity of the typhoid germ, as based upon the experiments made by Professors Jordan, Russell and Zeit, shows, the longevity of the typhoid germ under existing conditions in the Illinois River more correctly than does the experiment of Hiram F. Mills, the results of a chart plotted in a similar way to the one introduced in evidence by Mr. Hering would disclose, in a marked degree, the same conditions as to the relative pollution of the three rivers in question.

In addition to the foregoing testimony, the testimony of Professor Theobald Smith, of Harvard, the investigator who devised the colon test, which was employed not only by all the witnesses for the defendants in this case, but was also made use of by the bacteriologists of St. Louis in their investigation in connection with this lawsuit, is worthy of special emphasis in considering this problem of the comparative pollutions of the three rivers in question. And defendants, as bearing upon this point, present his testimony as follows:

"Q. Have you examined the data introduced by Professor Jordan in this case relative to the abundance of the colon bacillus in the waters of the Drainage Canal and upper Illinois?

"A. I have.

"Q. This data was colon determination for 1901, made by Professor Jordan at the laboratories at Peoria, Grafton and St. Louis, and introduced in evidence in this case?

"A. I have examined those figures.

"Q. Are you familiar with the results obtained by him upon the colon contents of the Illinois River at its mouth and of the Mississippi and Missouri Rivers?

"A. I made a particularly careful examination of his tables.

"Q. What would you infer from this data, assuming the method of examination to have been accurate and the results to have been reported exactly?

"A. I should assume that the colon bacilli had very largely disappeared in their passage down the Illinois River and that the colon content of the Illinois River at Grafton is therefore less than that of the Missouri and the Mississippi Rivers, or at least about the same. That is to say, the colon content of the Illinois at Grafton is not to any material degree superior to that of the tributaries of the Illinois River, and it is on the whole less than the colon content of the Mississippi River and the Missouri River, according to these tests.

"It would seem that the condition of the water at the mouth of the Illinois River was certainly not inferior, if not superior, to that of the Mississippi River and the Missouri River at these points, as I read the testimony in these tables.

"Q. On the whole, from the colon determinations, would you conclude that the Missouri River was more or less polluted than the Illinois or Mississippi?

"A. *The Missouri River is on the whole more polluted than the Illinois River.* According to these figures, there is not very much difference, but the benefit of the doubt rests with the Illinois River without any question. *Basing myself upon the colon tests, as I certainly should in all such examinations, I should make the table speak for itself*

"Q. So far as these colon determinations go, then, and so far as the inference drawn from the colon contents of

streams are warranted, what do those results show as to the sanitary condition of the Illinois River at its mouth as compared with the Mississippi River above Grafton and the Missouri River at Fort Bellefontaine?

"A. *I should say that the Illinois River was superior in its sanitary quality to either of the other rivers, the Mississippi and Missouri.*" (7298 and 7299.)

In addition to the foregoing testimony here submitted, as to the comparative pollution of the three rivers, the defendants desire to call the court's attention to the testimony of Dr. Ravold in regard to the colon determinations made by him in October and November, 1901, which testimony is in part as follows:

"Q. Do you know the percentage of colon bacillus that was found in the samples for October, 1901?

"A. Yes, sir; October, 1901, 53.6 per cent.

"Q. For October, 1901, the coli was found in 53.6 per cent of the cases?

"Mr. Jeffries: And for November?

"A. For November, 29.17 per cent.

"Q. Now, then, state the average for the two months.

"A. The average is 45 per cent.

"Q. Where did you say the laboratory was located?

"A. It was in the Dempsey house in Grafton.

"Q. Were these samples examined and worked on the day they were taken?

"A. Yes, sir; collected by the bacteriologists and they collected together as a rule and brought them right back to the laboratory and examined them at once.

"Q. How far is the laboratory situated from where the samples were taken?

"A. Three miles, on the Illinois." (245.)

The tables of coli determination at Grafton on the Illinois River for October and November, 1901, beginning with the 5th day of October, and ending with the 27th day of November, appear on page 246.

Taking the tests for October, 1901, the coli was found in 33.6 per cent. of the cases, and in November in 29.17 per cent. of the cases. Adding them together, we have 82.77 per cent., which, if divided by 2, gives 41.385 as the average, instead of 45 per cent., as figured by Dr. Ravold as the per cent. of cases in which coli was found for these two months in the Illinois River at Grafton.

In the Mississippi River the table for coli determinations two miles above Grafton, for October and November, 1901, appears on page 249; and Dr. Ravold testified in regard to the percentage as follows:

"Q. Can you give the percentage of instances in which the coli was found present in the samples taken from the Mississippi River above Grafton?

"A. This is Mississippi River water above Grafton. This is October. The Mississippi River, 33.33 per cent. Mississippi, for November, 62.50 per cent; total, 47 per cent.

"Q. For the two months?

"A. For the two months, yes."

And on pages 254 and 255 of Dr. Ravold's testimony appears the following:

"Mr. Jeffries: Missouri River at Fort Bellefontaine?

"A. Yes, sir.

"Q. That is how far from the mouth of the Missouri?

"A. Six miles above the mouth of the Missouri, where it empties into the Mississippi River.

"Q. Now, when did you commence taking samples of water there?

"A. Began October 4th.

"Q. Now, how soon after the samples were collected until they were plated?

"A. They were collected by one collector who took this one sample. He got that sample about 10 o'clock in the morning and returned at once to the laboratory, reaching there about 2 o'clock, between noon and 2 o'clock."

The tables for these coli determinations for October and

November, 1901, appear on pp. 255 and 256 of Dr. Ravold's testimony. The percentages for these tables for the Missouri River are found on page 276, in the following testimony:

"Mr. Jeffries: Now, get Bellefontaine.

"A. During the third period, the percentage of coli bacillus at Fort Bellefontaine in the Missouri River, October, 1901, is 92.6 per cent.; in November, 1901, 80 per cent. of the times The average of this is 86.2 per cent."

By comparing these percentages, we find in Dr. Ravold's testimony authority for the statement that the coli determinations made in October and November, 1901, for the Illinois, Mississippi and Missouri Rivers at the time that the joint investigation was made by him, representing St. Louis, and Professor Jordan, representing the Sanitary District, that the coli contents of the Illinois River at Grafton, according to his testimony, was 41.3 per cent.; the Mississippi above Grafton, 47 per cent.; and for the Missouri River at Fort Bellefontaine, 82.2 per cent., which shows conclusively that the Missouri River at that period was more polluted than the Mississippi, and the Mississippi River more polluted than the Illinois, based upon the coli determination as made and introduced in evidence by Dr. Ravold.

The testimony of the foregoing witnesses, set out in detail, cannot but bring home the conviction that the conclusion that the Missouri River is more polluted than the Illinois or the Mississippi has been established in this case beyond a reasonable doubt, by an overwhelming preponderance of scientific testimony, as the record in this case will disclose, and the scientific fact of that pollution is not at variance with the physical conditions that obtain upon the Missouri River when they are properly understood.

With St. Charles, Jefferson City, St. Joseph, Kansas City and Omaha, and other cities situated upon this water course, emptying their sewage into this stream, and considering that the time of flow from these cities to St. Louis is much less than the time of flow from the cities situated upon the Illinois,

or even the Mississippi—the facts demonstrated by the scientific testimony in this case establish a condition of pollution for the Missouri River that is in accordance with the physical conditions as they exist in connection with that stream. And defendants submit that the evidence in this case establishes and sustains the contention that the Illinois River at its mouth, from a sanitary standpoint, based upon chemical and bacterial analyses, is less polluted and less dangerous to health than is either the Missouri River or the Mississippi River, and the Illinois River, emptying into the Mississippi and Missouri Rivers, is contaminated and polluted by these two rivers instead of contaminating and polluting the combined waters of the Mississippi and Missouri Rivers.

VI.

SINCE THE OPENING OF THE DRAINAGE CANAL THE WATER OF THE ILLINOIS RIVER HAS BEEN IMPROVED FOR AGRICULTURAL, PISCATORIAL AND MECHANICAL PURPOSES BY VIRTUE OF ITS DILUTION WITH THE PURE WATER OF LAKE MICHIGAN.

The testimony of witnesses introduced by the defendants in this case establishes conclusively that since the opening of the Drainage Canal and the flowing of the sewage of Chicago, diluted with the pure waters of Lake Michigan, into the Desplaines and Illinois Rivers, the waters of the Illinois River from Morris to Grafton *have been improved for agricultural, piscatorial and mechanical purposes.*

It will be observed that in the upper stretches of the Illinois River, from Averyville to Morris, in the neighborhood where one would expect to find the greatest effect from the pollution coming from Chicago, manifested upon the fish life as the same existed in those rivers before and since the opening of the Drainage Canal, as well as the use of the water for mechanical purposes (such as the generating of steam, etc.), or for the watering of cattle along the river—that instead of finding a condition worse than that which existed prior to the opening of the Canal, the undisputed testimony in this case shows conclusively that the water has been greatly improved since the opening of the canal for the purposes heretofore stated, over the conditions as they obtained prior to 1900.

The defendants in this case took testimony along the Illinois River, beginning at Grafton, at the mouth, and came up the river by steamboat as far as La Salle, and from La Salle to Morris by rail, taking testimony in regard to these propositions above enunciated.

Defendants called to the witness stand at all these various places the representative business men, bankers, hotel keepers, clerks, lawyers, judges, members of the legislature ex-lieuten-

ant governors of the State and members of Congress, together with a great number of fishermen who lived upon the Illinois River, engaged in the occupation of catching fish for market. In addition, nearly all physicians practicing medicine in the Illinois River towns were called to testify in regard to the typhoid conditions existing along the Illinois River for a period before and since the opening of the Chicago Drainage Canal.

It is a matter of interest to note that the fishing industry upon the Illinois River is one of great magnitude, and in the year 1901 18,000,000 pounds of fish were taken out of the Illinois River, with quite a large percentage of fine fish added; which, measured by dollars and cents, amounted to nearly three-quarters of a million dollars. (3641.)

The number of people living upon the Illinois River in house-boats and tents, along the sloughs, bayous and bays, amount to more than 5,000 people. (3637.)

Since the opening of the Drainage Canal, as the evidence of these witnesses will disclose, there has been practically no typhoid fever among the fishermen who live upon the Illinois River and take their water supply from that river, or the people who live in the towns adjacent to said river.

In order to bring out these facts more clearly, the evidence in this case of the witnesses who were called at the different points along the Illinois River (and whose testimony appears in Volume 4 of the record) will be discussed briefly for each location.

Morris.

The water at this point was bad before the opening of the Drainage Canal and has been greatly improved since the opening. Prior to the opening of the Drainage Canal the odor from the river was very offensive, and this odor has practically all disappeared. The foregoing statement is sustained and established by the testimony of ten witnesses, appearing in the printed record at pp. 3855 to 3894.

Marseilles.

The condition of the river before the opening of the Canal was very bad, and since the opening of the Canal there has been a marked improvement, and fish that were natural inhabitants of pure water, such as the cisco, lake perch and pickerel, have made their appearance in the Illinois River at this point since the opening of the Canal, although they did not exist in these waters prior thereto. (3816.) Fourteen witnesses, the representative men of Marseilles, were called, whose testimony substantiates the foregoing statement, and their testimony appears at pp. 3815 to 3851.

Ottawa.

Prior to the opening of the Drainage Canal the water at this point, except in times of flood or freshets, was almost sewage water, with a very disagreeable odor; but since the opening of the Canal the conditions have greatly improved. The stench has disappeared and the water in every way has been bettered. Fish of a similar character to those found in Lake Michigan have been caught in the waters at Ottawa since the opening of the Drainage Canal, while the fish that existed in those waters prior to the opening of the Drainage Canal were not suitable for eating purposes. (3808.)

This statement of fact is supported and corrobrated by the testimony of six witnesses, among whom was the Hon. M. T. Maloney, lawyer, ex-mayor of Ottawa, and ex-Attorney General of the State of Illinois, whose testimony is worthy of great consideration upon this point. The testimony of these witnesses appears at pp. 3774 to 3811.

La Salle.

Prior to the opening of the Canal the water at this point was very dirty looking at times and green scum would form upon the water during the lower stages, and it had a very strong odor. There were practically no fish found in the river

at this point. Since the opening of the Canal the water has greatly improved over conditions which previously obtained. It has a better color; the fish will live longer in the water, and conditions, from appearances, have in every way greatly improved. There has been no increase of typhoid fever since the opening of the Canal, notwithstanding the fact that one-third of the water supply comes directly from the Illinois and Michigan Canal. The river at this point is utilized for pleasure purposes by pleasure crafts since the opening of the Canal, which was not the case prior thereto. These facts are substantiated and set out in the testimony of nine witnesses. (3719 to 3757.)

Henry.

The condition of the river since the opening of the Drainage Canal has improved over conditions which obtained prior thereto. There have been no deaths from typhoid fever at this point since the opening of the Canal. In the winters prior to 1900, when the river at this point was frozen, the fish in the river would die under the ice, and since the opening of the Canal that condition does not exist. No dead fish have been found in the river at this point since the opening of the Drainage Canal. The fish had a *tarry* taste before the Canal was opened, but since this has disappeared. The water of the river at this point is better for steam-making purposes now than it was prior to the opening of the Drainage Canal, as testified to by a steamboat man at this point. (3493.) The testimony of seven witnesses at this point corroborates and sustains the foregoing fact. (3466 to 3495.)

Lacon.

The condition of the river before the opening of the Drainage Canal was better than the condition of the river at Henry. The fish would not live under the ice in winter, and tasted of tar. There was an odor from under the ice in winter and a disagreeable odor in summer. Since the opening of the Canal the conditions of the water have been greatly improved in

every way. No typhoid fever (excepting imported cases) has existed in Lacon since the opening of the Canal. The steam-making qualities of the water since the opening of the Canal have been greatly improved over conditions prior thereto; and the boilers in the steamboats that use the water of the Illinois River since 1901 do not foam as they did prior thereto.

These statements are established by the testimony of nine witnesses who were called at Lacon. (3435 to 3462.)

Chillicothe.

The water before the opening of the Drainage Canal was in a highly polluted condition, but not so much polluted as conditions below Peoria. In the winter season, when holes were cut in the ice, the water would smell and fish would die in the nets shortly after they were caught, and in the winter fish had a taste of gas and tar that rendered them unfit for market. The scum which was observed below Peoria, and which attached itself to the nets, did not appear in the water at Chillicothe, which is above Peoria. A kind of gas emanated from under the ice after a hole was cut through which resembled the smell of gas or tar. Since the opening of the Canal the water has greatly improved. Fish live better in live-boxes. The water is not as contaminated, much clearer, fish thrive better, the scum and odor is absent from the water, and there is no typhoid fever existing among the fishermen.

According to the testimony of L. S. McCulley, stationary engineer for six years, and also engineer upon the steamboats running from Copperas Creek to Henry, in regard to the mechanical uses of the water for steam-making power, the conditions are as follows: "That since the opening of the Drainage Canal there has been no more odor than comes from natural, clear water, and that foaming has been absent, and there has not been as much lime or boiler scale, of which there was a good deal before the opening." (3433.) Fourteen witnesses were called to establish the foregoing proposition. (3374 to 3431.)

Pekin.

The condition of the water at this point before the opening of the canal was exceedingly foul and bad smelling; fish did not thrive and the conditions were worse than further below on the Illinois River. But since the opening of the Drainage Canal the conditions have greatly improved, but not as much as at Havana, Beardstown and points below. Distilleries are located at this point. Four thousand four hundred head of cattle are fed under one roof in the Globe Distillery. (2329.) The American Distillery Company feeds about four thousand head of cattle. The excreta from the cattle sheds goes out on the bank of the river and into the Illinois River in both cases. Prior to the opening of the Drainage Canal, dead fish would accumulate at the locks in such quantities that a steamboat would not carry them. (3371.)

The islands of manure at this point and at Peoria were broken from the shore by the use of a steamboat, and allowed to float down the river. (3372.)

During the two and a half years since the opening of the canal, only four deaths have occurred in the City of Pekin from typhoid fever. These facts, as above set forth, are testified to by the managers of the Globe Distillery, the Health Commissioner of Pekin, the president of the American Distilling Company, the Mayor of the town and a steamboat man by the name of Losch. (3327 to 3372.)

Havana.

The water at this point was considerably more polluted prior to the opening of the Drainage Canal than at points further down the river. The effects on fish were more manifest than further below. The slime collected on the nets at this point was in greater abundance than at points further down the river. At this point was first noted the presence of the large islands of offal from the cattle sheds at Peoria and Pekin, and

one in particular was unable to pass through the piers of the bridge located at this point crossing the Illinois River.

The scum and odor from the water was very offensive before the opening of the canal, but since the opening of the canal, the water has become clearer and purer. The fish have lived better and the slime, while more evident at this point than at Beardstown below, has been considerably mitigated, and the general sanitary conditions of the water have been greatly improved, and no typhoid fever exists in this town.

A number of fishermen drink the water of the Illinois River at this place. The foregoing facts are established by eight witnesses that were called and testified in this case. (3286 to 3322.)

Beardstown.

The condition of the water at Beardstown prior to the opening of the canal in low water was highly polluted, having a thick scum on the surface during low stages of water. In the winter fish died under the ice; fishermen complained of the presence of a slimy substance, which collected on their nets, known as "slurgut", which substance appeared in great abundance. The odor from the water was very offensive and disagreeable. According to the health officers, no typhoid fever existed before or since the opening of the canal. Since the opening of the canal the water has been clearer; the presence of this slime has not been so pronounced; the odor and scum from the water have disappeared and the general sanitary condition of the water has been greatly improved.

The foregoing statement is supported by the testimony of six witnesses. (3255 to 3273.)

Meredosia.

At this point in the river the fish are better than they were before the opening of the canal (3218), and there has been in the last three years not one-half dozen cases of typhoid fever, and those cases were not attributed to the waters of the Illinois. (3226.)

Prior to the opening of the canal, a green scum formed upon the water and vegetation grew in the river, but since that time all this has disappeared.

The water at this point, before the opening of the canal, foamed and was bad for the boilers, according to S. D. Allen, who has charge of the pumps of the Wabash Railroad, it has been better for steam making purposes since the opening than it was prior thereto. (3230.)

These facts are substantiated by nine witnesses living in Meredosia, who testified in this case. (3211 to 3228.)

Naples.

Naples is situated about thirty-eight miles from Kampsville and about thirty-six miles from Pearl and twenty-five miles from Beardstown and thirteen miles from La Grange dam. The waters of the Illinois River, prior to the opening of the Drainage Canal, were much more foul than the water at Kampsville or Grafton. In low water it was very stagnant and foul, and fish would not live in it. During the summer a scum would form on the water, and there was quite an odor. A kind of substance would form on the nets of the fishermen like grease and called by the fishermen "slurgut." Fish would die in the nets under the ice in winter. Since the opening of the canal the water has greatly improved in every respect over conditions that obtained previously. No typhoid fever exists among the fishermen who drink the water of the Illinois River.

These facts are proven by five witnesses who live in the Town of Naples. (3192 to 3208.)

Pearl.

At this point, prior to the opening of the Drainage Canal, when a hole was cut through the ice, gas would emanate from the water, and dead fish would be found under the ice, and also a filthy scum was on the water. Since the opening of the canal these conditions have disappeared and the fish

thrive much better in the waters of the Illinois than they did formerly.

These facts are substantiated by five witnesses called at this point. (3167 to 3186.)

Kampsville.

The water at this point before the opening of the Drainage Canal at low water stages was very stagnant; had a green scum on it, an offensive odor, and fish in low water stages would not live in live boxes. But since the opening of the canal the water is clearer, purer, free from offensive odors; fish live better in live boxes than before; no typhoid fever observed since the opening of the canal and no sickness among the fishermen, and malarial fever has been on the decrease. Prior to the opening scum would form on the nets of the fishermen. There are about forty fishermen at this point, most of whom drink the water of the Illinois River.

These facts are substantiated by thirteen witnesses. (3052 to 3152.)

Hardin.

Hardin is situated forty-one miles from the mouth of the river. The condition of the water here was similar to the condition at Grafton before and since the opening of the canal, with the exception that in times of low water the greenish scum was completely across the river. Prior to the opening of the canal the odor at times was so offensive as to reach several blocks away from the river; there are now about twelve or fifteen fishermen located at this point, most of whom drink the water. The improvement in the river since the opening of the canal has been marked by the absence of odor and green scum, with clear water, and fish live better in live boxes since the opening of the canal than before. There has been no typhoid fever in the town or among the fishermen using the water for drinking purposes.

Twenty witnesses were called, who substantiated by their testimony the foregoing statements. (2994 to 3050.)

Grafton.

The Illinois River at this point, where it empties into the Mississippi, prior to the opening of the Drainage Canal, was at times a stagnant water, and at times contained a number of dead fish floating down from points above. In the summer the water was not drunk by the fishermen. Since the opening of the canal the water is clearer and colder and is drunk by practically all of the fishermen. There has been no typhoid fever at this point or sickness among the fishermen caused from drinking the water, notwithstanding the fact that this is the point where a great amount of fish is caught and a great number of men are engaged in the fishing industry. The condition of the water has improved since the opening of the canal.

Fifteen witnesses were called at Grafton, and these facts are substantiated by their testimony. (2934 to 2989.)

As touching upon the question of the improvement of the water of the Illinois for mechanical purposes, Mr. Peter M. Casey, manager of the Corning Distillery Company at Peoria, testified: "I consider that it is very much improved in every way, especially for mechanical purposes." (3514.)

Captain Percy M. Swain, of the steamer Fred Swain, plying between Peoria and La Salle, and who has been operating this boat since 1892, describes in his own way the condition of the river before the opening of the Drainage Canal in 1900 as follows:

"Q. Will you describe the condition of the river before the opening of the Drainage Canal in 1900?

"A. Well, prior to the turning in of the drainage there was very little current, and there was a green scum formed on the river and the water was not clear. The water had the appearance more of a kind of—in the lake here a kind of white appearance, more like sewage color, you know, and in places, for instance the locks there, it had this greenness. It would also form on the gates, and also form on the boat, and this kind of a white stuff, and a considerable odor came from the water.

For instance, Lacon, where there was much of a current, there would be an odor there, and also at the locks. In the winter time, when the water was frozen over, there was more or less dead fish, and where they took up the nets, in fishing, there was more or less odor, more than there is since the turning in of the drainage. The river is altogether different now than it was prior to the turning in of the drainage. * * * It is clearer and this green scum does not form any more, only in places like, for instance, Lake Depew, or, for instance, the Illinois River where there is no current. * * * Heretofore it was necessary to clean the boilers once a week, every week, but of late once in two weeks is sufficient.

"Q. Do you observe any difference in the water above the Peoria Bridge from the conditions below the Peoria Bridge? (3567.)

"A. Why, above the bridge the water is considerably different from the water below the bridge. Below the bridge, where it gets the sewage from stock yards and packing houses, it has a thick, heavy, mushy appearance. Two hundred or three hundred feet from land you can see this stuff bubble up before you, or within two or three hundred feet of the shore you see the bubbling up. This stuff rises up in the bottom that way, a black appearance, an awful appearance, but we always stop the pumps before getting in there to keep from pumping this stuff into the boilers and causing the stoppage of the pipes, and it has a kind of rotten smell coming off of it, or odor, a kind of rotten smell like. It is a matter of knowledge. I have been there and seen it." (3568.)

Mr. Alexander Richardson, a jeweler, who has lived in Peoria over thirty years, and has fished for thirty years on the Illinois River, testified that the fish are harder and firmer and of a better flavor, "and since the opening of the canal and the coming in of the water, we catch larger fish, such as bass and pike, which we did not catch before." (3575.)

Mr. Charles S. Bartson, who was formerly in the wholesale fish business at Peoria, testified:

"Whenever we got a bad winter below Peoria, it killed a great many of fish. In summer I have seen fish come to the top by hundreds, the gas killed them. When there was ice on the river they got so bad we could not use them. Since the opening of the Drainage Canal the character of the water in the river above Peoria has been good, and I have not known of the fish dying under the ice since. * * * The fish lived in live boxes three or four times longer than they did before." (3586.)

Mr. J. N. Feger, who lived in Peoria thirty years and fished on the river all his life with hook and line from Havana to Henry, stated that "prior to the opening of the Drainage Canal I considered the water bad; it was scummy and green and sluggish and had an odor. Its effect on the fish was very bad; they were very soft. I know down here at Pekin the city had to hire people to go and bury them. Since the opening of the Drainage Canal the water has been better, the condition of the fish better and the water above Peoria has been better than the water below Peoria." (3589.)

Mr. R. R. Bourland, the secretary of the Illinois River Valley Association, a resident of Peoria, testified:

"Above Peoria it is certainly a great deal better now than it was before 1900. The water is clearer in color and does not get so low in low water and therefore does not have the disagreeable features of the former low stages of water. * * * Below Peoria the water still shows the effect of the offal from the factories, but not to the same extent as before, because of the greater volume of water, and I find the odor not nearly so apparent as it was before. * * * Before 1900 the use of the river for pleasure craft was almost entirely given up during low stages of water. Since that time there is continued use of the river by a great many people for pleasure purposes. I do not think that there were any houseboats, as they are called, on the river before 1900, and there are now quite a number, which are used for summer residence by a number of people for mere pleasure." (3591 to 92.)

Mr. Nat. H. Cohen, president of the Illinois Fish Commission since 1897, testified as follows:

"Q. Is there a large fishing industry on the Illinois River?

"A. Yes, from five to ten thousand people are employed on the river from La Salle to Grafton, and bringing into the state probably $500,000 and shipping out from twelve to fifteen million pounds of fish per annum. From all the information I got along the river, they say there is less malaria and scarcely any typhoid fever among the fishermen for the last three years. They tell me they drink the water now and they could not drink it before." (3607.)

And in regard to the condition of the fish, he testified that he became acquainted with the Illinois River by fishing in all the lakes from Havana to Meredosia. (3597.)

* * * "In the spring, during the freshet, I couldn't tell much difference in the water, but as the summer came on and the water receded from the banks, the water became stagnant, little or no current, covered with a green scum and a bad odor. The lakes adjacent were low and of very high temperature, destroying fish from decayed aquatic matter, destroying what we term 'plankton'. Plankton is the vegetable and animal life in the water that the fry or small fish live on. The temperature became so high that that was all destroyed. * * * Since that time in the same lakes, the temperature is much lower, the water much clearer, and we find an absence of dead fish. Before the opening of the canal above Peoria, as a general thing, the coloration of the fish was much lighter, and they did not have the tenacity of life that they have now. Since the opening of the Drainage Canal I think the fish are much better, those that I have seen." (3600.)

Captain S. P. Bartlett, who is the field superintendent of the United States Fish Commission, and has occupied that position about thirty-one years, and who is also one of the Board of the State Fish Commissioners of Illinois, and has served consecutively for twenty-four years, and who has been intimately associated with the Illinois River for over thirty years, testified as follows:

"Q. Prior to the opening of the Drainage Canal, what was the character of the current of the Illinois River?

"A. Well, that would depend upon the season of the year. In the early spring and after the snow and water had reached the river, the current at times would probably reach a mile or a mile and a half an hour, of course, being swifter at places. Later in the season, when the water was lower, it has been frequently impossible to tell which way the current was going by an object on the surface. It was very sluggish, very slow.

"Q. Prior to the opening of the Drainage Canal, what was the condition of the water of the Illinois River between La Salle and Henry dam?

"A. Well, the water was about on the average of river water; in high water, reasonably clear; in low water there would be the incidental amount of vegetable growth, and more or less impurities.

"Q. Do you know whether, prior to the opening of the Drainage Canal, there was an odor in summer in the water above the Henry dam?

"A. Well, there was an odor, more or less, as I remember it. It was given off, as all low water does. It was from decaying and refuse matter dumped into it. * * * I have seen the stage of water so low in the Illinois River during the winter season that the fish would perish under the ice during the winter. The ice becomes very thick and covered with a heavy blanket of snow; it stops the introduction or escape of any air, and the water, I think, becomes bad. It forms noxious gas under there, which is very destructive to fish and other life. The water becomes impure. * * * I have known fish above Henry to die previous to the opening of the canal for many seasons. * * * The strong fish always has a dark brown color. Since the opening of the Drainage Canal the condition of the Illinois River above Henry dam, from personal observation of it, and going over it frequently, my judgment would be that the water shows a decided improvement in every way. Since the opening of the Drainage Canal I know of no com-

plaint about fish. They are way up to the average. * * * It would be probably better to say that these vegetable growths are due as a rule to the outgrowth of low water and high temperature, and I have almost every season, when we have had a low stage of water, found a large amount of vegetable growth on the surface and moving upwards and forwards with the change of the wind. * * * Well, if there is in any way a large amount of it and the water is very low, decomposition takes up a great deal of it, and a great deal of it is consumed by vegetable consuming fishes and aquatic birds. In very low water a very great deal of it is left upon the shore and decomposes, which is frequently the cause of a great deal of bad odor. * * * Since the opening of the Drainage Canal, the Illinois River between Henry and Peoria—my observation has been that the water was very much better and clearer.

"Q. At Peoria are there foreign substances deposited in the river, and if so from what sources?

"A. Yes, from all sources. The sewage is very large and the refuse from the gas house and distilleries and glucose factories is immense. * * *

"Q. Below Peoria, have you noticed this foreign matter in the water?

"A. Yes, sir, in great quantities. * * * Principally the large deposit of offal from the distilleries and from the cattle pens breaking off and falling into the river in large masses; in the immense amount of sewage that collects at the river front during an east wind, driving it all onto the shore, the water keeping it all on the shore, and particularly in the operation of the seine in collecting the fish. We find a very offensive deposit on all the shores along the river and the flat lakes adjoining. * * * The deposit looks like a greasy substance, a slime I might call it, a very heavy slime. It is very offensive when brought to the surface. I am talking now about below Peoria. * * * I have met this condition frequently as far down as Havana, in limited quantities, of course. Havana is close to seventy miles below Peoria.

"This particular refuse from the gas works and distilleries and glucose factories is run off in spouts at the edge of the water, and it is allowed to accumulate there, and when the very low water comes it breaks off and floats off with the current. That would be an impossibility if the stage of the water was of sufficient height to keep the shores clean. * * * If the river was rising, and at such times this stuff would break off from the shores very easily, it was taken in great quantities into this lake (Spring Lake); in fact, I have seen it in bulk sufficient to absolutely prohibit the going in with our boats. We had to break it up before we could go by. I found the bottoms of those ponds frequently eight inches deep with this black slime, where there was only six or eight inches of water. * * * I took occasion to go over the ground several times in later seasons, and have always found a very bad state of affairs there. Since the opening of the canal I have made a good many investigations of Spring Lake. * * * I have spent a great deal of time on the lake looking after the condition of the fish.

"Q. Well, what has been the condition since the opening of the canal?

"A. Well, again I will have to go back a little bit and make an explanation so you can understand the conditions. At that season of the year the water was warm and the boat lay at Copperas Creek dam and I took occasion to make a critical examination of a number of black bass brought in by those who had been fishing on the lower end of Spring Lake, to satisfy myself as to the fish themselves. I found in a great many instances the fish very soft, and took occasion to open them up and found that the whole of the interior of the fish was absolutely dissolved, from what cause I am not prepared to state, further than that a few days later a great quantity of black bass were floating upon the water in the lower end of the lake, and a post-mortem disclosed a similar state of facts, that all of the digestive organs of the fish had been absolutely dissolved. The fish died, of course. I had no means of making an analytical examination of the liquid, but I was satisfied, as far as I

could be from observation, that the cause of death was the very impure state of the water at that time. * * * Since the opening of the Drainage Canal I do not believe that there has been a season when any dead fish have been found upon the lake. My own particular observation of that locality is that the water is very much clearer, and a personal examination of the bottom, while it shows quite a deposit, is very slight as compared to the seasons of which I speak. * * *

"The condition has been that since the opening of the Drainage Canal, of course, there has been a very much greater volume of water. The water has been very much better. I have noticed a very great decrease in vegetation of various kinds. *The best evidence that we have, if you will permit me to express it, of the increased betterment of the water at points below Copperas Creek, is the fact that there are more black bass in the river this year than I have ever known.* Since the opening of the Drainage Canal between La Grange and Kampsville, the condition of the water in my opinion has been good. The fish have been good, in fine condition. As I stated a moment ago, there are more black bass, which are only habitants, as a matter of choice, of clear water. I am speaking of the river proper now. From La Salle to Peoria, since the opening of the Drainage Canal, the water has improved until we get to Peoria Lake. From Peoria to Copperas Creek the water improves as you go down.

"Q. Is the water in the Illinois River below Peoria and down to Copperas Creek better or worse than in Peoria Lake?

"A. Well, I think the water below Peoria, from Peoria to Copperas Creek dam, is worse than Peoria Lake considerably, very considerably, except under extraordinary conditions. *There is rarely a better body of water found anywhere than in Peoria Lake.*

"Q. How does the water below Copperas Creek and down to La Grange dam compare with the water above Copperas Creek?

"A. I think it gets better all the time as you go further

below, a great deal better. *A man does not have to be an expert to notice that. You can see that all the time; the character of water is better as you go down.*" (3621 to 3633.)

Again Captain Bartlett says:

"My impression would be that there is anywhere from 2,500 to 3,500 people directly interested in fishing, themselves; that does not include, however, the helpers. I am talking about the men who fish. The number of people engaged in the preparation of the fish for market and the shipping of them after they are caught, including the fishermen themselves, I should think 5,000 would be a fair estimate.

"Q. What was the condition of health of this class of men prior to the opening of the Drainage Canal as to typhoid fever and malarial fever and malarial diseases?

"A. Well, I can only speak of that in a general way as to my own men particularly. We had a great deal of sickness, not much typhoid, but a great deal of very low grade fever, that in my opinion—well, I was going to say as a physician, but from what knowledge I have of it was owing to a very bad state of the water during low water.

"Q. Were you educated for a physician and did you at one time practice medicine?

"A. I never practiced medicine. I was educated and graduated as a physician—too poor.

"Q. Since the opening of the Drainage Canal what has been the condition of the health of the people engaged in business on the Illinois River in the fishing industry?

"A. My observation has been that there has been a very great decrease in typhoid and intestinal diseases. * * * My work, as you know, carries me to almost every town along the Illinois River, and the natural tendency would be to talk over semi-professional matters with physicians, and I believe, with one single exception, that every physician that I have talked to has commented on the decrease in typhoid and malarial fever during the last two or three years.

"I should be inclined to say, from all sources of informa-

tion, that the health of the fishermen is a great deal better. My opinion is that there would be more than 5,000 people directly upon the river in tents, flatboats and houseboats and on the sloughs and bayous and bays and lakes connected with the Illinois River. * * *

"The growth of interest in fishing and sport on the Illinois River has been great and almost every available lake on the river of any size has been taken up for pleasure resorts. Wherever they can they put down a driven well, but in a great many places that I know of they are using the water for drinking and domestic purposes. * * * The Illinois River is very peculiar in its formation, in that it has flat shores on both sides of the river; these bottoms extending from three to fifteen miles in width and flat almost in every case, with lakes and sloughs aside from the river itself; as the fall is only one-half inch to the mile, the overflows are frequent, and the lakes fill up and evaporate again several times during the season—during the dry season. The course of the river is inclined to be free from bars and of very even depth. The river in extreme high water * * * will be from bluff to bluff frequently from twelve to fifteen miles wide.

"Q. Do you know whether domestic animals adjoining the river are accustomed to drink its waters?

"A. Oh, yes, all the time. The lowlands above Havana particularly, and a great many other places, are used for pastures. (3639.)

"Q. Did you ever hear of a disease called anthrax among the cattle of the Illinois River?

"A. I have not among the cattle of the Illinois River, no. I have heard of the disease.

"Q. Do you know or did you ever hear of any disease among cattle drinking of the water of the Illinois River which was attributed to the drinking of the water of the river?

"A. No, sir." (3630 to 3640.)

Cross-Examination.

"Q. You know nothing of the condition of the water from a sanitary standpoint other than what you have testified?

"A. Well, I heard you say a while ago that you didn't care to go into expert testimony in that case. My investigations are all along that line, and I do not care to go into it unless you want me to."

Mr. William H. Binnian, president of the Acme Harvesting Company and the Peoria Straw Board Company, who employs on an average of about 700 men in his factory, testified as follows:

"Before the opening of the Drainage Canal the Illinois River was a pretty filthy stream and quite sluggish. The river was very much more filthy below the city than above on account of refuse matter thrown in by the manufacturing plants on the river bank. Since the opening of the canal, to all appearances it has cleared it up very materially, and practically we have found that it has been a very great benefit, that is, particularly through the straw board mill.

"Q. What is your opinion as a manufacturer as to the quality of the Illinois River at present for manufacturing purposes and the use to which water is put in manufacturing?

"A. Why, I am firmly convinced that it is far superior to-day to what it was prior to the opening of the Drainage Canal, by practical experience and scientific tests that have been made at both plants at times. *I do not think it can be excelled. It is a most excellent water for manufacturing purposes, for steaming purposes. We use about two and a half million gallons of water per day at the straw board plant.*" (3642 to 3645.)

Mr. W. F. York, captain of a steamboat and who has steamboated since 1850 on the Illinois River, testified:

"Since the opening of the Drainage Canal above Peoria, I think it (the river) has been better than it was before the Drainage Canal was put in, better for steaming purposes. Below

Peoria for steaming purposes it was very bad before the opening of the canal; boilers would foam, but since the opening of the canal it has been considerably better than it used to be. It has been purer and there has not been so much dirt in it. We have never had any trouble since the drainage was put in." (3653.)

Mr. R. D. Clarke, the general manager of Clarke Brothers & Company, distillers; president of the Thomas & Clarke Cracker Manufactory, and president of the Peoria Board of Trade, testified as follows:

"Q. How does the water of the Illinois River compare today with what it did before the opening of the Drainage Canal in the manufacture of steam and for mechanical uses of the water?

"A. It is better for boiler purposes. * * * The boilers don't seem to have the tendency to foam that they used to have when pushed pretty hard." (3672.)

Also he stated:

"I have seen thousands of dead fish along the river below Peoria, but I don't remember seeing them above upper Peoria Bridge, before the opening of the Drainage Canal." (3674.)

The foregoing testimony of what might properly be denominated the *lay witnesses*, as distinguished from the expert witnesses, shows a wonderful parallel existing between the conditions of the Illinois River as observed by these people, who have lived upon the banks of the river and spent most of their time upon the stream, when compared with the results of purification as disclosed by the chemical and bacterial analyses already commented upon under a different heading.

It is a remarkable fact that the evidence of a great number of the witnesses who testified in this case, from Morris to Grafton, who have made no chemical or bacterial examination of the waters, but merely testified about the conditions as they saw them, shows a progressive purification of the Illinois River which begins at Morris and terminates in a condition of purity such as is disclosed by the testimony of Captain Bartlett, wherein he

states that there is "rarely a better body of water found anywhere than in Lake Peoria." And to use his language again: "A man does not have to be an expert to notice that. You can see that all the time. The character of the water is better as you go down."

Not only does the evidence of these witnesses residing along the Illinois River disclose the progressive purification that has taken place in the Illinois River from Morris to Peoria, and again from Peoria to Grafton (as far as appearances and odor are concerned), but the purification of the river, as indicated in the life of the fish which now thrive in this stream, shows that their condition since the opening of the Drainage Canal is infinitely superior to what it was prior thereto, indicating in a remarkable manner the purifying effect of the waters of Lake Michigan upon the waters of the Illinois River.

Fish being the natural inhabitants of water, the purification of the Illinois River since the opening of the Drainage Canal is emphasized by the presence in those waters of such fish as bass, pickerel and lake perch, which before 1900 had entirely disappeared from those waters on account of its polluted condition.

When the enormous fishing industry that has developed along the Illinois River during the last three years is considered, it speaks eloquently for the purification that has taken place in the Illinois River.

That the water of the Illinois River has been improved for mechanical and manufacturing purposes, admits of no question when the testimony hereinabove quoted is duly considered. And in view of the fact that the State of Missouri charges the defendants in this case in its bill of complaint with injuring the waters of the Mississippi for manufacturing purposes, and have failed to offer any evidence to sustain that position, it is unnecessary to comment further upon this point.

That the water of the Mississippi is not injured for agricultural purposes (by that meaning the watering of stock) is conclusively proven by the testimony of Captain Bartlett in

regard to the pasturing of cattle along the Illinois River and the absence of anthrax among the cattle thus pastured.

Complainant in this case may contend, based upon the speculative opinions of Mr. Gardner S. Williams, and other witnesses, that anthrax is a water-borne disease, and hence the farmers living along the Mississippi on the Missouri shore are liable to be affected by having their cattle contract anthrax from that water. But this proposition that anthrax is a water-borne disease is discussed in another part of this brief. It is sufficient to say at this point that the evidence in this case fails to disclose the presence of this disease existing among the cattle, either those fed at Peoria or Pekin, or along the banks of the Illinois River or its tributaries; and hence there can be no danger to the farmers of Missouri from the conditions proven to exist in the State of Illinois.

Defendants contend that the water at Grafton since 1900, and at points above, is in a better condition for manufacturing purposes and for agricultural purposes than it was prior to 1900, and that since 1900 fish live and thrive more vigorously in the Illinois River than ever before; consequently, the condition of the water at Grafton, as established by the testimony hereinbefore quoted, could not affect, injuriously, the water of the Mississippi, thereby rendering the Mississippi River water less valuable for manufacturing and agricultural purposes.

The defendants in this case contend that the evidence, which is not contradicted, establishes the fact beyond all reasonable doubt that since the opening of the Drainage Canal the water of the Illinois River has been improved for agricultural, piscatorial and mechanical purposes by virtue of its dilution with the purer water of Lake Michigan; and hence could not possibly injure or damage the water supply of the State of Missouri.

VII.

THE TYPHOID CONDITIONS EXISTING IN THE CITY OF ST. LOUIS, AS EVIDENCED BY ITS PUBLISHED HEALTH STATISTICS, CANNOT BE CHARGED, IN WHOLE OR IN PART, TO THE SANITARY DISTRICT OF CHICAGO.

The most important fact in this controversy, overshadowing all others, and absolutely necessary to be established in order to sustain the contentions of complainant, is that the City of Chicago is the direct, immediate and approximate cause of the typhoid fever conditions existing in the City of St. Louis.

The typhoid conditions in St. Louis, as disclosed by the number of deaths under typhoid fever reported in the published reports of the St. Louis Board of Health, has been accepted by complainants as showing the true typhoid conditions existing in the City of St. Louis.

The defendants in this case join issue with complainant upon that proposition and contend that the true typhoid conditions in St. Louis are not disclosed by the number of deaths reported under the heading of typhoid fever in the public health reports of that city. But, assuming, for the sake of argument, that the Board of Health reports truly state the number of deaths occurring in the City of St. Louis from typhoid fever, the important fact showing a connection between the typhoid conditions in St. Louis as thus disclosed and the City of Chicago has not been, and cannot be, established by the evidence in this case.

It is a remarkable fact that men occupying positions in the sanitary world so prominent and conspicuous as the witnesses who have testified in this case on the part of complainant should accept, without question, as true the number of deaths reported and published under typhoid fever by the Board of Health of the City of St. Louis, as showing conclusively the typhoid conditions existing in that city.

But however remarkable and astounding that proposition

may seem, it fades into insignificance when these same experts unqualifiedly assert that those deaths as appearing in St. Louis are due to the typhoid conditions existing in the City of Chicago since the opening of the Drainage Canal. Knowing that typhoid fever cases exist in great numbers upon the watershed of the Missouri River and the Mississippi River and the Illinois River, exclusive of Chicago, and knowing that no scientist, however skilled, would be able to discover a typhoid germ in the water going into the intake tower of the St. Louis waterworks, and assuming that he was able to discover such a germ, he would not be able, in the light of any scientific knowledge that exists to-day, to show that such a germ came from Chicago and did not come from some other place nearer at hand. nevertheless, in order to establish a connection between the typhoid conditions in St. Louis and Chicago, all other sources of infection were brushed aside by some of these eminent experts, as matters of no consequence, and they asserted, unhesitatingly, that in their opinion the increase in typhoid conditions in St. Louis since 1900, as evidenced by the reports of deaths under typhoid fever, as published in the health reports of that city, was due to the opening of the Drainage Canal.

In order to show that the increase of typhoid fever in St. Louis, based upon the reported deaths, has not been established as coming from the City of Chicago, defendants desire to submit, in part, the testimony of Mr. George C. Whipple, one of the witnesses who testified for complainant in this case.

On cross-examination Mr. Whipple was asked this question:

"Q. Is it your opinion, and I believe you stated, that the increase in typhoid in the City of St. Louis is due to the sewage from the Drainage Canal from 1900, 1901 and 1902?

"A. I think that I stated that under certain conditions which were assumed, the most probable cause of the increased typhoid in the City of St. Louis during that period was due to the sewage of Chicago, *meaning by that that was the easiest explanation of the increase under the conditions which were assumed.*" (2091.)

And, again, he was asked this question:

"Q. You cannot state, as an established fact, that the opening of the Canal at Lockport is the cause of the increase in typhoid in St. Louis, can you?

"A. I cannot state it as an established fact, absolutely and conclusively proven." (2095.)

Notwithstanding the fact that Mr. Gardner Stewart Williams, a witness for complainant, in his testimony stated: "It is my judgment that to the discharge of sewage by the Sanitary District of Chicago is attributable the major part of the increase in typhoid fever, revealed by the typhoid statistics of the City of St. Louis since the beginning of 1900, as compared with the former period." (2463.)

He also stated, on cross-examination, in answer to the following question:

"Q. Have you ever been able to identify any bacilli of typhoid found in the Mississippi River above the intake as being indigenous to Chicago and not coming from the other towns located upon the watershed of the Mississippi River, above its intake, the Missouri and Illinois?

"A. Certainly not; and it would be absolutely impossible to do so, any more than it would be possible to determine from what source a potato came that you might find floating in the river.

"Q. Would the fact that you found a potato floating in the river prove that it came from Chicago?

"A. Certainly not." (2576.)

Nevertheless, in view of the foregoing answers, the witnesses called by complainant unqualifiedly testified that the increase of typhoid fever in St. Louis since 1900 was due to the opening of the Drainage Canal.

In order to present this matter clearly to the court, assuming that the reported typhoid deaths in St. Louis, since 1900, are due in whole or in part to the opening of the Drainage Canal—a consideration of the relationship existing between the reported typhoid deaths—by the month—in the City of St.

Louis and those in the City of Chicago, will shed some light upon this connection.

Taking into consideration the time necessary for a typhoid germ to pass from Chicago to St. Louis (assuming that such a germ could survive the journey between Chicago and St. Louis), also taking into consideration the period of incubation and the time of the disease preceding death—a comparison between the monthly typhoid deaths in Chicago and those occurring in St. Louis for the period before 1900, with that since 1900, will show conclusively that no relationship exists between the typhoid in St. Louis and the typhoid in Chicago.

In order to present this clearly to the court, the evidence of Professor Jordan is herewith set out in part as touching upon this question, together with the testimony of other witnesses called by the defendants in this case.

"Q. Have you examined the typhoid mortality statistics of the City of St. Louis as evidenced by the reports of the Board of Health of the City of St. Louis?

"A. I have.

"Q. Have you examined the typhoid mortality statistics of the City of Chicago as evidenced by the reports of the Board of Health of the City of Chicago?

"A. I have.

"Q. Have you prepared a table of typhoid deaths based upon those reports?

"A. Yes, sir, I have a table of the deaths reported from typhoid fever in St. Louis by months from January, 1890, to December, 1903, inclusive, and I have a similar table for Chicago for exactly the same period.

"Q. Will you produce and read the mortality typhoid statistics of the City of St. Louis and the City of Chicago as compiled by you from the Board of Health reports of those two cities, covering said periods?

"A. They are as follows:

Typhoid Fever—St. Louis.

Month.	1890	1891	1892	1893	1894	1895	1896
January	11	5	13	36	2	12	4
February	4	9	8	17	7	3	4
March	6	4	7	8	8	3	3
April	4	10	9	8	14	7	4
May	8	9	3	3	5	6	9
June	8	11	6	2	11	6	6
July	12	17	15	11	21	9	13
August	19	12	8	42	24	17	29
September	27	32	23	32	32	9	13
October	18	26	45	20	20	15	9
November	16	11	111	25	20	13	7
December	7	16	189	11	7	7	5
	140	162	442	215	171	107	106

Typhoid Fever—St. Louis.

Month.	1897	1898	1899	1900	1901	1902	1903
January	7	4	10	19	8	14	15
February	9	6	7	5	14	16	15
March	7	7	4	16	11	11	20
April	4	6	5	4	4	14	17
May	7	2	2	4	8	11	15
June	9	7	5	8	6	7	16
July	10	9	9	15	13	14	27
August	18	9	6	20	31	26	37
September	17	14	16	13	24	21	42
October	17	12	15	30	32	32	29
November	15	7	32	13	27	31	24
December	5	12	20	19	20	25	31
	125	95	131	168	198	222	288

Typhoid Fever—Chicago.

Month.	1890	1891	1892	1893	1894	1895	1896
January	53	67	311	41	46	30	87
February	136	61	187	30	26	21	89
March	103	71	76	41	27	26	65
April	45	136	56	58	30	30	33
May	82	408	70	56	31	30	31
June	107	167	55	60	31	18	44
July	86	200	211	55	37	36	58
August	115	182	179	76	52	59	64
September	95	198	138	86	71	76	87
October	72	171	92	81	68	90	89
November	67	150	67	43	38	60	60
December	47	186	47	43	34	42	44
	1008	1997	1489	670	491	518	751

Typhoid Fever—Chicago.

Month.	1897	1898	1899	1900	1901	1902	1903
January	38	29	44	23	26	21	97
February	46	32	24	14	16	14	54
March	41	71	18	27	15	20	49
April	19	94	23	23	20	16	33
May	13	67	25	19	24	24	26
June	23	35	28	17	9	22	21
July	27	55	41	26	55	44	29
August	42	45	62	34	83	193	59
September	48	65	58	34	74	165	82
October	61	62	44	38	102	78	45
November	44	56	43	39	54	72	56
December	35	55	32	43	31	132	36
Total	437	636	442	337	509	801	588

"Q. What relation do the monthly deaths from typhoid in Chicago bear to those in the City of St. Louis, the period from 1890 to 1903, inclusive?

"A. From these tables I am unable to discover any relation between the monthly deaths from typhoid fever in Chicago and those in St. Louis.

"I have compiled from these tables a statement showing those months of maximum typhoid fever in Chicago and St. Louis and those showing the minimum deaths from typhoid fever in these two cities.

"The month showing the largest number of deaths in Chicago precedes the maximum in St. Louis

by 11 months in one year (1892),
by 8 months in one year (1903),
by 6 months in one year (1891),
by 5 months in two years (1896 and 1898),
by 3 months in one year (1899),
by 2 months in one year (1902).

"The Chicago maximum coincides with the St. Louis maximum in five years, namely: 1893, 1895, 1896, 1897 and 1900.

"The minimum typhoid fever in Chicago precedes the minimum in St. Louis in six years, namely: 1891, 1893, 1898, 1900, 1902. The Chicago minimum coincides with St. Louis minimum in two years, 1892 and 1890, and follows the St. Louis minimum in seven years, 1890, 1894, 1895, 1896, 1897, 1901 and 1903.

"Q. Have you made a study of the typhoid death statistics of the City of St. Louis and Chicago covering that period?

"A. Yes, sir; I have examined these very carefully and the results are set forth in the tables as just recorded.

"Q. Is an increase in the death rate from typhoid fever in St. Louis preceded by a corresponding increase in the death rate from typhoid fever in Chicago?

"A. It is not.

"Q. Is a decrease in the death rate from typhoid fever in Chicago followed by a decrease in the death rate from typhoid fever in St. Louis?

"A. I am unable to discover any relation between the monthly deaths from typhoid fever in Chicago and those in St. Louis. A decrease in the number in Chicago is not followed by a decrease in the number in St. Louis, nor is an increase in the deaths in St. Louis preceded by a corresponding increase in the deaths in Chicago.

"Q. If the typhoid fever in St. Louis, for the period from 1890 to 1903, inclusive, was caused by infection coming from the City of Chicago, would not some relation exist between typhoid conditions in Chicago and the typhoid conditions in St. Louis?

"A. I should certainly expect to find some relation obtaining between the prevalence of this disease in Chicago and that in St. Louis.

"I should anticipate that in general if the typhoid fever conditions in St. Louis were dependent upon those in Chicago that a large number of deaths from typhoid fever in the latter city would be followed within three or four months by an increase in the number of typhoid deaths in St. Louis.

"No such relation appears in the monthly record of typhoid fever of these two cities as tabulated.

"It is therefore my judgment that typhoid fever conditions in St. Louis are unaffected by a large amount or a small amount of typhoid fever in Chicago.

"Q. What relation do flood waters in the Illinois River bear to the increase or decrease of typhoid fever deaths in the City of St. Louis?

"A. I have prepared a table showing the water gauge readings obtained by the United States engineer at Kampsville Lock by months, for the years 1899, 1900, 1901 and 1902. These are the means of tri-daily readings. The readings are referred to the lower miter sill or 7 feet below low water.

"I find on comparing these readings of the heights of water in the Illinois River at the Kampsville Lock, that high water occurred in March, 1899, and low water in September, 1899. The maximum typhoid fever in St. Louis in that year occurred

in the month of November and the minimum typhoid fever in the month of May.

"In 1900 the high water period was again in the month of March and the lowest water recorded in January. The maximum typhoid fever in 1900 was in the month of October and the minimum in the months of April and May. In 1901 the maximum height of water occurred in the month of April and the low water period in October. The maximum typhoid fever in St. Louis occurred in the month of October and the minimum in the month of April. In 1902 the maximum high water occurred in the month of July, and the minimum in the month of January. The maximum typhoid fever in St. Louis occurred in the month of October and the minimum in the month of June.

"A very interesting comparison may be made between the months of July, August, September, October and November, 1901 and 1902. The water in the Illinois River averaged nearly twice as high in 1902 as in 1901, and yet the typhoid fever at St. Louis was almost exactly the same in the latter part of those years as is shown by reference to the tabulated table of monthly deaths.

"Q. When there is low water in the Illinois River, what effect does that stage of water have upon the increase or decrease of typhoid fever in St. Louis?

"A. From an examination of the tables just referred to I am unable to discover any connection between the stage of low water as disclosed in the gauge reading at Kampsville and a large amount or small amount of typhoid fever in St. Louis.

"In the four years for which record is at hand, absolutely no relation exists between low water in the Illinois River as shown in the gauge readings at Kampsville and an increase or decrease in the typhoid mortality in the City of St. Louis

"Q. Is a high death rate from typhoid fever in Chicago, during cold weather, followed by correspondingly high death rate from typhoid fever in the City of St. Louis, allowing for the period of incubation and distance of flow between Chicago and St. Louis?

"A. From an examination of the monthly deaths reported from typhoid fever in St. Louis, I am unable to discover any such relation between a high death rate from typhoid fever in Chicago in the winter month and the typhoid mortality in St. Louis, two or three months later, when allowance is made for the periods of incubation and time of flow between Chicago and St. Louis.

"Thus, in December, 1900, the number of deaths reported from typhoid fever in the City of Chicago was the largest reported for any month in that year. In the early months of 1901 in St. Louis no marked increase of death appears as a consequence of the large number of deaths in Chicago.

"Again, in 1902, the number of deaths from typhoid fever for Chicago in December and also in January, 1903, was very extensive, but the number of deaths in St. Louis in March, April and May, 1903, was not materially in excess of those in the preceding year, when the number of typhoid deaths in Chicago for the corresponding months of January and December had not been one-fourth as great." (6278, 6284.)

Also the testimony of Professor W. P. Mason, which is, in part, as follows:

"Q. Have you prepared any charts based upon the typhoid fever mortality, as reported in the Board of Health reports of the City of St. Louis, as compared with the typhoid fever mortality as reported in the Board of Health reports for the City of Chicago, by months, for 1900 and 1901, and 1902 and 1903?

"A. I have prepared those charts.

"Q. Will you produce the chart for 1900 and 1901, and the one for 1902 and 1903, and make them a part of the evidence?

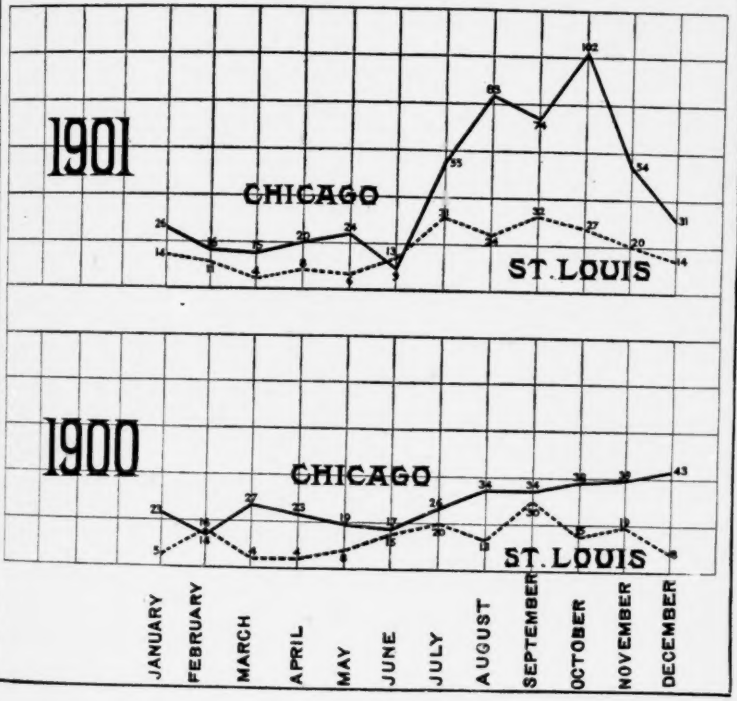
"A. Yes, sir. The caption of these charts is: 'Deaths from Typhoid Fever as reported in Chicago and St. Louis Official Health Reports.' The tables in St. Louis are plotted one month in advance, that is, February deaths are plotted as of January.

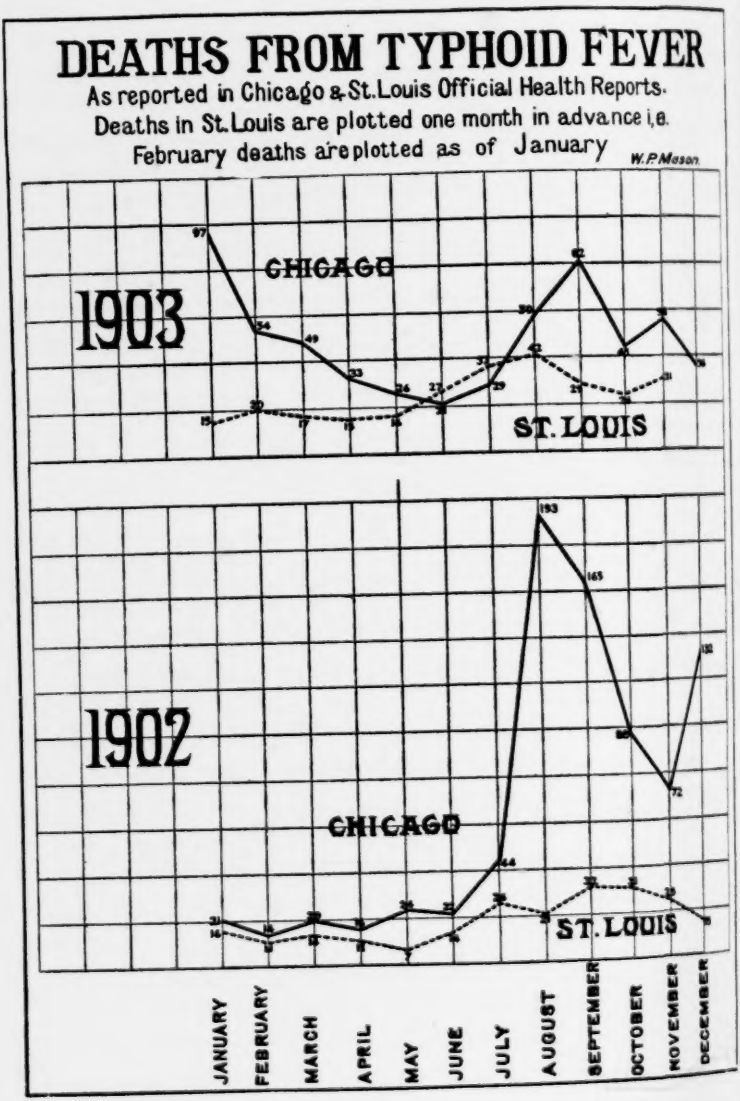
"The charts are as follows:

DEATHS FROM TYPHOID FEVER

As reported in Chicago & St. Louis Official Health Reports.
Deaths in St. Louis are plotted one month in advance i.e.
February deaths are plotted as of January.

W. P. Mason.




DEATHS FROM TYPHOID FEVER
As reported in Chicago & St. Louis Official Health Reports.
Deaths in St. Louis are plotted one month in advance i.e.
February deaths are plotted as of January
W.P.Mason
1903
CHICAGO
ST. LOUIS
1902
CHICAGO
ST. LOUIS
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

"Q. Will you please state from what data the charts themselves were made?

"A. The data from which these charts were made was obtained from Professor Jordan's testimony and afterwards checked from the official records as published by the St. Louis and Chicago Health Boards.

"Q. Please state what the chart shows relative to the relationship existing between typhoid fever in the City of St. Louis and the City of Chicago?

"A. The deaths from typhoid fever in Chicago are plotted upon the chart in a solid black line and are given for the twelve months of the years 1900, 1901, 1902 and 1903, the number of deaths in each month being stated upon the chart.

"The deaths from typhoid fever in St. Louis are plotted on the same chart in a black dotted line, the deaths in the successive months being stated in numbers upon the chart along such dotted line. The deaths in St. Louis are stated one month in advance, that is, the five deaths in St. Louis in February, 1900, are stated as of January, 1900. The fourteen deaths in St. Louis in March, 1900, are stated as of February, 1900, and so on throughout the entire dotted lines. The reason for stating the St. Louis deaths one month in advance is because of the length of time that it would take a typhoid fever germ, should it go as far as St. Louis, to get there, and because of the length of time that it would take to produce typhoid fever of fatal character after the invasion of the victim had taken place. In other words, if typhoid fever occurring in Chicago in January should produce typhoid fever in St. Louis, the deaths from such fever in St. Louis would be occurring in the month of February. It is for that reason that, for purposes of future comparison, February deaths in St. Louis are compared with January deaths in Chicago, March deaths in St. Louis with February deaths in Chicago, April deaths in St. Louis with March deaths in Chicago, and so on.

"In examining this chart and observing the fluctuations of the solid line representing deaths in Chicago and of the dotted

line representing deaths in St. Louis, I observe that the two lines are by no means parallel. In other words, in January, 1900, we have 23 deaths in Chicago corresponding to 5 deaths in St. Louis.

"In February, 1900, the Chicago deaths have dropped to 14.

"We do not have a corresponding drop in St. Louis. We have the reverse. We have a rise from 5 to 16.

"In the following month of March we have a rise in the deaths in Chicago and a drop in the deaths in St. Louis.

"In the following month we have a slight drop in the deaths in Chicago from 27 to 23, and the same deaths in St. Louis, namely, 4 in March and 4 in April.

"In the next month, namely, in May, there is a drop from 23 to 19 in Chicago and a rise in St. Louis from 4 to 8.

"In the next month, June, there is a further drop in Chicago from 19 to 17, and a rise in St. Louis, from 8 to 15.

"In the next month, July, there is a rise from 17 to 26 in Chicago, and also a rise in St. Louis from 15 to 20.

"In the following month of August, there is a rise in Chicago from 26 to 34 and a drop in St. Louis from 20 to 13.

"In the following month of September there is no variation in Chicago, 34 to 34, and a rise in St. Louis from 13 to 30. In the following month of October there is a rise in Chicago from 34 to 38, and a drop in St. Louis from 30 to 15.

"In the following month of November there is a rise in Chicago from 38 to 39, and also a rise in St. Louis, from 15 to 19.

"In the following month of December there is a rise in Chicago from 39 to 43 and a drop in St. Louis from 19 to 8.

"In 1901, there is in January, 1901, a drop in Chicago from 43 to 26, and a rise in St. Louis from 8 to 14.

"In the month of February there is a drop in Chicago from 26 to 16, and also a drop in St. Louis, from 14 to 11.

"The next month, of March, there is a drop in Chicago from 16 to 15, and also a drop in St. Louis, from 11 to 4.

"In the following month of April there is a rise in Chicago from 15 to 20 and also a rise in St. Louis from 4 to 8.

"In the following month of May there is a rise in Chicago from 20 to 24 and a drop in St. Louis from 8 to 6.

"In the following month of June there is a drop in Chicago from 24 to 9 and a rise in St. Louis from 6 to 13.

"In the following month of July there is a rise in Chicago from 9 to 55 and also a rise in St. Louis from 13 to 31.

"In the following month of August there is a rise in Chicago from 55 to 83, which is a large one, and a drop in St. Louis from 31 to 24.

"In the following month of September there is a drop in Chicago from 83 to 74 and a rise in St. Louis from 24 to 32.

"In the following month of October there is a rise in Chicago from 74 to 102 and a drop in St. Louis from 32 to 27.

"In the following month of November there is a drop in Chicago to 54 and also a drop in St. Louis, 27 to 20.

"In the following month of December there is a drop in Chicago from 54 to 31 and also a drop in St. Louis, from 24 to 14.

"For the year 1902, for the month of January, 1902, there has been a drop in Chicago from 31 to 21 and a rise in St. Louis from 14 to 16.

"For the month of February there has been a drop in Chicago from 21 to 14 and also a drop in St. Louis, from 16 to 11.

"In the month of March there has been a rise in Chicago from 14 to 20 and also a rise in St. Louis, from 11 to 14.

"For the month of April there has been a drop in Chicago from 20 to 16 and also a drop in St. Louis, from 14 to 11.

"For the month of May there has been a drop in Chicago from 16 to 24 and a drop in St. Louis from 11 to 7.

"For the month of June there has been a drop in Chicago from 24 to 22 and rise in St. Louis, 7 to 14.

"For the month of July there has been a rise in Chicago, from 22 to 44, and also a rise in St. Louis, from 14 to 26.

"For the month of August there has been a great rise in Chicago, from 44 to 193, and there has been a drop in St. Louis from 26 to 21.

"For the month of September there has been a drop in Chicago from 193 to 165 and a rise in St. Louis from 21 to 32.

"For the month of October there has been a decided drop in Chicago, from 165 to 98, and a drop also in St. Louis, from 32 to 31.

"In the month of November there has been a drop in Chicago from 98 to 72 and also a drop in St. Louis, from 31 to 25.

"In the month of December there has been a rise in Chicago from 72 to 132 and a drop in St. Louis from 25 to 15.

"For the year 1903. For the month of January there has been a drop in Chicago from 132 to 97 and no variation in St Louis.

"For the month of February there has been a drop in Chicago from 97 to 54 and a rise in St. Louis from 15 to 20.

"For the month of March there has been a drop in Chicago from 54 to 49 and also a drop in St. Louis, from 20 to 17.

"For the month of April there has been a drop in Chicago from 49 to 33 and also a drop in St. Louis, from 17 to 15.

"For the month of May there has been a drop in Chicago from 33 to 26, and a rise in St. Louis from 15 to 16.

"For the month of June there has been a drop in Chicago from 26 to 21 and a rise in St. Louis from 16 to 27.

"For the month of July there has been a rise in Chicago from 21 to 29 and also a rise in St. Louis, from 27 to 37.

"For the month of August there has been a rise in Chicago from 29 to 50 and also a rise in St. Louis, from 37 to 42.

"For the month of September there has been a rise in Chicago from 59 to 82 and a drop in St. Louis from 42 to 29.

"For the month of October there has been a drop in Chicago from 82 to 45 and a drop also in St. Louis, from 29 to 24.

"For the month of November there has been a rise in Chicago from 45 to 56 and also a rise in St. Louis, from 24 to 31.

"For the month of December there has been a drop in Chicago from 56 to 36, and for St. Louis I have no data, because everything has been shoved one month in advance and conse-

quently I am short of data for the month of December for St. Louis.

"Q. Professor, from your examination of the monthly mortality from typhoid fever in the City of St. Louis and in the City of Chicago for the years 1900, 1901, 1902 and 1903, what conclusion do you draw as a sanitarian and epidemiologist as to the cause of typhoid fever conditions in the City of St. Louis being attributable to typhoid conditions that exist in the City of Chicago?

"A. From an examination of the charts just presented I am of the opinion that no relation whatever exists between the typhoid fever as represented in Chicago and as represented in the City of St. Louis. In other words, I am strongly convinced that typhoid in St. Louis is not produced by typhoid fever in Chicago.

"It will be seen from an examination of those charts that the curves of typhoid fever are far from being parallel for the two cities. In many instances the rise of the curve from Chicago is co-incident with the falling of the curve for St. Louis, particularly so for the month of August, 1902, when the typhoid in Chicago grows from 44 to 193 and the typhoid in St. Louis drops from 26 to 21." (6926 to 6932.)

Also the testimony of Dr. Theobald Smith, which is in part as follows:

"Q. If it were true that a relation obtained between typhoid fever in Chicago and typhoid fever in St. Louis, would you not expect this relationship to be shown in an indication between typhoid rates in Chicago and in St. Louis?

"A. I should think that the two curves of typhoid would be very much alike and the St. Louis curve would be slightly retarded in time.

"Q. I call your attention to two charts entitled 'Deaths from Typhoid Fever as reported in Chicago and St. Louis Official Health Reports. The deaths in St. Louis are plotted one month in advance, *i. e.*, February deaths are plotted as of January, W. P. Mason,' which chart was offered in evidence

by Professor Mason, and shows the monthly death rate from typhoid fever for the years 1900, 1901, 1902 and 1903. Assuming that the facts from which those charts are made to be true, what is your opinion as to whether or not there is any relationship or connection between the typhoid rates in Chicago and in St. Louis, as evidenced by these charts?

"A. I am unable to see any direct connection between the typhoid curve of Chicago and that of St. Louis from these diagrams. The upward curve in the St. Louis charts is one which seems to correspond with the usual summer and fall increase in typhoid which is manifested throughout the civilized world, but I fail to see any direct relation between the two.

"Q. Is there a rise in typhoid in the fall in other cities in this country aside from Chicago and St. Louis?

"A. I think it is generally conceded that typhoid fever in our hospitals grows in August, September and October, each year. It is the time when cases are looked for.

"Q. Have you examined the typhoid statistics which have been introduced in evidence in this case showing the typhoid fever upon the three watersheds of the Illinois, Mississippi and Missouri Rivers, the typhoid fever conditions in St. Louis and the typhoid fever conditions in Chicago?

"A. I have looked over the figures as presented to me.

"Q. Knowing what you do regarding the watersheds of the Mississippi and the Missouri Rivers and the number of deaths from typhoid fever occurring in the cities draining into those rivers, would, in your opinion, the waters of the Mississippi River at the Chain of Rocks be suitable for a public water supply without filtration, supposing that the sewage of Chicago were entirely eliminated?

"A. From the colon determination of the Mississippi River at that point I should hardly consider the river water a satisfactory water for public use without previous preparation or previous filtration.

"Q. Knowing the typhoid condition in the City of St. Louis, and assuming that the same was due to water supply,

where would you look for the source of infection, to points as far away as the City of Chicago or to points nearer than the City of Chicago?

"A. I should first look to the points nearer by all means, and if those should be eliminated then I think I should look to the City of Chicago.

"Q. From a consideration of the typhoid fever upon the watershed tributary to St. Louis would it be reasonable to eliminate the point near at hand in looking for the source or cause of infection in St. Louis, assuming that it came from a water supply?

"A. I think it would be highly important to locate the nearest sources first, because of the vulnerability of the typhoid bacillus in water. The further the area of infection the less the danger of the typhoid bacilli reaching the water supply. A few bacilli discharged into a stream nearby would be much more dangerous than a large number discharged at a much greater distance." (See Vol. 8, 7303, 7304.)

Also, Professor Victor C. Vaughan testified, in part, as follows:

"Q. Have you seen the charts offered in evidence by Professor Mason, which charts have the caption 'Deaths from typhoid fever as reported in Chicago and St. Louis,' by said health reports. 'Deaths in St. Louis are plotted one month in advance, i. e., February deaths are plotted as of January, W. P. Mason.' That is where the typhoid deaths of St. Louis and of Chicago are plotted by the month?

"A. Yes, I have seen those charts. I saw them this morning.

"Q. From a study of the typhoid conditions as assumed in the hypothetical questions put to you in regard to St. Louis and the condition in Chicago as evidenced by these charts, what is your opinion as to whether or not the typhoid conditions in St. Louis bear any relationship to or are consequent of the typhoid conditions that exist in Chicago for the last four years?

"A. These charts certainly would indicate that there is no

causal relation between typhoid fever in Chicago and typhoid fever in St. Louis, because if there was the charts would have the same general curve, charting the typhoid fever in St. Louis one month later than the typhoid fever in Chicago, and such a relation is not shown by these charts." (See Vol. 8, p. 7328.)

Mr. John W. Hill's testimony upon this point is set out in part as follows:

"Q. I call your attention to two charts introduced in evidence and sworn to by Professor W. P. Mason under the caption 'Deaths from Typhoid Fever, as Reported in Chicago and St. Louis Official Health Reports, the deaths in St. Louis p'otted one month in advance, i. e., February deaths are plotted as of January,' and ask you to look at these charts, assuming them to be based upon correct statistics and properly plotted and ask you to state whether the typhoid deaths in St. Louis bear any relationship to the typhoid conditions that obtain in the City of Chicago.

"A. An examination of the diagram for the year 1900 to 1903, inclusive, in which the solid lines show the charted deaths by months for the City of Chicago and dotted line the same data for City of St. Louis for each of the years embraced, and in which in the legend at the top of each of the pair of diagrams a statement is made, and considering the statement in the legend at the head of the two pages before me, showing that the deaths in St. Louis are plotted one month in advance, namely, that February deaths are plotted as of January, presumably for the purpose of comparison of the deaths in St. Louis directly with the deaths from typhoid fever in Chicago, it does not appear that the typhoid fever death rates from St. Louis are coincident in intensity with the typhoid fever death rates of Chicago. This is especially true for the years 1901 and 1902 and 1903. For which years the diagrams show that when the rate is rising in Chicago it is declining in St. Louis, and when it is declining in Chicago it is sometimes rising in St. Louis, and that the wide ranges in the typhoid fever death rate as shown in the diagram for the City of Chicago are not

reproduced in the diagram showing typhoid fever death rates for the City of St. Louis, and it would not be possible in my opinion to connect the rates in one city with the other. In fact there might be just as close an agreement between the typhoid fever rates of the City of Chicago and Philadelphia if plotted together in this manner as there is between the typhoid fever death rates of the cities of Chicago and St. Louis, and clearly the typhoid fever rates of Chicago can have in this manner no influence whatever upon the typhoid fever rates of Philadelphia. There is nothing on the face of the four diagrams to indicate a connection between the typhoid fever death rates of the two cities." (See Vol. 8, pp. 7556, 7557.)

"Q. Assuming that typhoid fever germs should be found in the Mississippi River at the Chain of Rocks, do you know of any way of determining from what sources such germs originated?

"A. Taking into consideration all the facts and considering the three drainage basins, namely, the Illinois, the Mississippi and Missouri, upon each of which are found many cities, some of considerable population, like Peoria and Chicago on the Illinois Drainage Basin, and Dubuque, Davenport, Burlington, Des Moines, Rock Island, Moline and Quincy on the Mississippi River basin; Kansas City, Topeka, St. Joe and Omaha on the Missouri basin, in all of which cities it is probable that typhoid fever prevails during the usual season of typhoid fever, and in some of these cities prevails at all times, and especially keeping in mind the larger cities close to St. Louis, it would be wholly impossible, in my opinion, to say from what city the typhoid fever organism found in the Mississippi River opposite St. Louis would come. If it were true that any one of the cities on either of the watersheds not too far removed from St. Louis had typhoid fever while the other cities on the other watersheds did not have it, after allowing for the usual time between the infection of the stream and the discovery of the organism at St. Louis, it might be charged to that city, whichever one it might be, but statistics show that in all the

larger cities of the country typhoid fever always prevails, and where the drainage of three watersheds combined, as in the Mississippi River in front of St. Louis, I know of no process whereby the typhoid fever organism there found could be assigned to the probable locality from which it came." (See Vol. 8, pp. 7550, 7551.)

Also:

"Q. From a study of all the typhoid statistics as they obtain along the watersheds of the Missouri River, the Mississippi River, the Illinois River, the City of Chicago and the City of St. Louis, and assuming that the increase of typhoid fever cases as evidenced by the death rate in St. Louis, and disclosed by the Board of Health reports of the City of St. Louis, under typhoid fever deaths there reported and taking into consideration all chemical, bacterial and other knowledge which you possess, what is your opinion as to whether such increase in typhoid fever, assuming there was an increase as above indicated in St. Louis, since the opening of the Drainage Canal, can be attributed to the opening of the Drainage Canal as the direct, immediate and proximate cause of such increase beyond all reasonable doubt?

"A. If the typhoid fever statistics of St. Louis show an increase in the rates per unit of population since the opening of the Drainage Canal and the investigation clearly indicates that there is no other possible source of infection and the rates in St. Louis rise correspondingly with the rates in Chicago and fall correspondingly with the rates in Chicago, it might be held that such increase in the unit rates for typhoid fever in St. Louis could be charged to the flow of sewage through the Drainage Canal, but in view of the possibility of infection from other urban centers than Chicago, and especially in view of the possible infection of the St. Louis water supply from typhoid fever prevailing in Peoria, I should hesitate to charge to the flow of Chicago sewage through the Drainage Canal any increased typhoid rates shown in the City of St. Louis since the opening of the canal unless the evidence clearly disclosed

the fact that as the rates raised in Chicago they raised in St. Louis and as they declined in Chicago they also declined in St. Louis. In other words, unless the rates in St. Louis showed that they corresponded with the rates of the city supposed to be the cause, I am led to this opinion by the much nearer source of infection in the City of Peoria, where typhoid fever prevails during the usual season of typhoid and doubtless is found prevailing to some extent throughout all the months of the year. Or, in other cities of large population upon the watershed of the Mississippi and Missouri Rivers. While one cannot positively say that the sewerage of Chicago might not contribute to this or certainly does not contribute to this, it is equally out of the question to assert that a single city discharging its sewage into one of the rivers constituting the drainage area of the river which went in front of the St. Louis intake is the sole cause or at all the cause of the increase of rates in the City of St. Louis. Too many factors enter into the proposition such as is contained in the question to justify one in asserting that typhoid fever is due to any one of the several possible centers of infection lying on the drainage basin above the City of St. Louis.

"Q. Assume that the City of St. Charles, located within 47 miles of the intake tower of the St. Louis waterworks, containing a population of 7,000, with more typhoid fever present than in the City of Peoria, which City of Peoria is located 286 miles above the City of St. Louis, what would be the comparative effect of these two cities upon the water supply under the conditions assumed?

"A. The smaller city, namely, St. Charles, being nearer the point of intake above the City of St. Louis, in my opinion would constitute a greater menace to the water supply of that city than would the larger City of Peoria, situated five times as far away in point of distance from the intake of St. Louis, even though the normal rate of typhoid fever were the same in the two cities. I have always believed and can point to no evidence that contradicts this belief, that the nearness of the

point of infection rather than the size of the urban or rural center, is the chief factor in determining infection. That the little city near by in which typhoid fever prevails is more to be feared than a large city far distant, even though the same unit rate of typhoid is found in each." (See Vol. 8, pp. 7555, 7556.)

The testimony based upon the deaths reported from typhoid fever in the City of St. Louis by the months, compared with the typhoid deaths in the City of Chicago, reported in the same manner, and as is set forth graphically in the chart presented in the testimony of Professor Mason, shows no connection or relationship existing between the typhoid conditions in the two cities; and, without discussing the question that the typhoid deaths reported as such in the published reports of the City of St. Louis, do not correctly show the true typhoid conditions in the City of St. Louis, which will be discussed subsequently under a special heading, the evidence in this case fails utterly to establish that the typhoid conditions in St. Louis since 1900 are due, in whole or in part, to the opening of the Drainage Canal. The affirmative of this proposition devolves upon the complainant to establish; but the evidence in this case, based upon the statistics themselves, and as illustrated in the charts prepared by Professor Mason, demonstrates and illustrates conclusively that the typhoid conditions existing in the City of St. Louis, as evidenced by its published health statistics, cannot be charged in whole or in part to the Sanitary District of Chicago.

VIII.

THAT THE WATER SUPPLY OF ST. LOUIS IS POLLUTED AND INFECTED DEFENDANTS DO NOT DENY, BUT THEY ASSERT THAT THE INFECTED MATERIAL BRINGING ABOUT THIS CONDITION IS DERIVED, NOT FROM CHICAGO, BUT FROM TOWNS, VILLAGES AND RURAL COMMUNITIES MUCH NEARER IN POINT OF TIME TO THE ST. LOUIS INTAKE AT THE CHAIN OF ROCKS.

The defendants contend that the evidence in this case, as already cited, establishes the fact beyond all question that the water supply of the City of St. Louis is polluted and infected, but the evidence does not show that that pollution and infection is due to the opening of the Chicago Drainage Canal or is derived in any way from the City of Chicago.

It is a principle universally recognized by sanitarians and epidemiologists that the nearby sources of pollution are the most important and first to be considered in an epidemiological inquiry. The most extensive water borne epidemics of typhoid fever that have occurred in the United States and elsewhere have been caused by infection from a rural population situated close to the source of public water supply. (6276.)

Dr. Rayold, one of complainant's witnesses, testified that "other conditions being equal, the probabilities of contamination by reason of the presence of the typhoid bacillus would be greater the nearer the place of the introduction of the bacteria to the place of the consumption of water." (943.)

"If you had one hundred men with typhoid fever discharging sewage into the river at the mouth of the Illinois River, at Grafton, the danger to St. Louis would be much greater than if one hundred men were discharging their typhoid fever discharges into the Illinois River at Lockport from the Drainage Canal." (944.)

Professor W. P. Mason testified as follows:

"Q. When considering questions concerning typhoid fever, do you regard it as important to note the interval of time

elapsing between infection of water supply and the drinking of the infected water?

"A. I regard that as very important. That is a topic upon which I have pretty strong opinions and which I have quite an amount of data.

"Q. State fully the reasons for your answer?

"A. I have made an analysis of 205 British epidemics reported by Hart in a report entitled 'Water Borne Typhoid,' made to the Parliamentary Committee of the British Medical Association. A very full report is obtained in that report of Hart's, not only of the deaths, but of the character of the water supply causing them, and I have divided those 205 epidemics into three portions: Those that were produced by well water, those that were produced by stream and reservoir water, and incidentally those that were produced by milk. Then I had left over some that I could not classify and I have left them out of the count.

"In 33 epidemics due to stream and reservoir water I have found that the death rate was 9.85 per cent. of the cases.

"In 75 epidemics due to well water I found that the death rate was 11.83 per cent. of the cases, and I found that in 20 epidemics due to milk the death rate was 12.79 of the cases, showing that a well water epidemic was distinctly more serious in character than an epidemic caused by water which had carried the typhoid germ some distance from the point of infection to the point where the water was used for purposes of drinking.

"I made an examination of 357 cases of typhoid fever in a typhoid fever epidemic which I examined in Waterville, and I was able there to follow the course more clearly of each case and to get the physician's statement whether the case was a severe one or a mild one. Some of these cases used the city water supply, which was from a contaminated stream. Some of the cases used well water supply and those wells were contaminated. Some of those cases used both sources of water. I found that among the cases that used city water only 41.41

per cent. were severe, it not being stated whether they were fatal or not; I rated a fatal case as a severe one, naturally.

"Among those cases not using city water I found that 61.29 per cent. were severe, thus showing that the typhoid fever produced by the city water was a milder type, and my explanation of that is that the typhoid germ having to struggle for existence in a river under adverse circumstances, when it arrives at the point where the water is drunk, is not capable of producing so much poisonous material, or, in other words, not capable of producing so severe a case of fever if it produced one at all.

"In the opinion of Mr. George C. Whipple, who testified in this case, which opinion was given on the witness stand in the case of the Maine Water Company against the City of Waterville (I was on that case and heard him testify), he made use of the expression 'Immediate póllution is very much more dangerous than remote pollution,' a view which is entirely in accord with my own views.

"Q. Professor, assume that on April 1, 1895, the total number of wells in the City of St. Louis was 4,846, and assume that pursuant to an order of the Board of Health of St. Louis, directing the examination of these wells, that the City Chemist, after an examination of 59 of these wells, condemned them as being unsanitary; and assume further that in August, 1895, upon the report of the City Chemist condemning seven more of these wells, the Board of Health of the City of St. Louis passed a resolution to the effect that the City Chemist should make no further examination of the wells in question, and since 1895 none of these wells has been condemned, what effect would this number of wells in the City of St. Louis have, in your opinion, upon the typhoid conditions existing in the said city, assuming that the water of these wells was used by the inhabitants for drinking and domestic purposes?

"A. Taking all the assumptions stated in the question, I believe that the water of those wells was responsible for a portion of the typhoid fever in St. Louis, because I am a be-

liever in greater danger coming from a polluted well water than from the water of a polluted stream. (6936-39.)

"I would attribute any increase in typhoid fever which might have taken place in St. Louis to infection from nearer points, because of what I have already testified as to my belief that the nearer the point of infection the greater the danger, and because, further, that the charts which I have offered in evidence show that there is no relation between the typhoid fever in Chicago and typhoid fever in St. Louis." (6941.)

Professor Lewellys F. Barker, of the University of Chicago, testified as follows:

"In my opinion the probability of infection or pollution of the water supply of St. Louis, assuming the above, would be the largest from those places within the mean flow of five to seven days. I don't know how to express that—from those places where the average flow or the mean flow is within five to seven days of St. Louis. I think the probability of infection or pollution from the great distances requiring more than 12 days, for example, would be remote." (7108.)

Mr. John W. Hill testified:

"The City of St. Charles, being nearer the point of intake above the City of St. Louis, in my opinion, would constitute a greater menace to the water supply of that city than would the larger City of Peoria, situated five times as far away in point of distance from the intake of St. Louis, even though the normal rate of typhoid fever were the same in the two cities. I have always believed, and can point to no evidence that contradicts this belief, that the nearness of the point of infection, rather than the size of the urban or rural center, is the chief factor in determining infection. That the little city near by in which typhoid fever prevails is more to be feared than a large city far distant, even though the same unit rate of typhoid fever is found in each." (7555.)

Professor Jordan testified as follows:

"It has been observed that where a community is served by an infected water supply there are often fewer cases of

typhoid fever in the periphery of the town at a distance from the central source than there are close to the point where the water is pumped into the mains. In other words, the greater the distance from the source of infection the less the intensity of the disease. The nearer the source of infection the more severe the incidence. (6272.)

"Typhoid fever is as a rule more prevalent in rural than in urban districts, and the near by infection from the rural population on a watershed is an important factor to be considered in passing judgment upon the water supply of a city using river water for domestic and drinking purposes." (6275.)

Such absolute unanimity of opinion among all the witnesses testifying in this case renders still more surprising the assumption of complainants, who pass by the manifold sources of infection, urban and rural, which are within 48 hours flow of the St. Louis water intake, in order to fasten suspicion upon the City of Chicago, one of the most distant points from which, under any circumstances, infection could possibly be supposed to come.

Wells in St. Louis.

The number of wells in the City of St. Louis in 1895 was 4,804, of which 437 were public wells (6687). These wells, as defendants contend, were a source of infection and a means of spreading typhoid fever in the City of St. Louis, and were of themselves an immediate, direct and continuous menace and danger to the inhabitants of the City of St. Louis.

On page 12 of the 17th Annual Report of the Health Commissioner of St. Louis appears the following:

"The examination by chemical tests of water taken from surface wells in different parts of this city progressed memorably during the year, and a number of these sources of contaminated water supply for households have been condemned. The standard of allowable impurity established for the purpose of this undertaking is quite liberal, but even as thus measured, very many wells were found to contain water utterly unfit for human consumption."

On page 63 of the same report appears the following:

"Number of samples of well water analyzed, 2. Private wells, 239; public wells, 8. Number of impure wells reported for condemnation: private wells, 41; public wells, 5."

On the same page, among other things, appears the following:

"Although the analyses of wells thus far made do not represent every ward in the city, the comparatively large number of wells found to be impure averaging about 1 out of 5, fully justify the vigorous continuation of these examinations. The Sanitary Division has already presented a list of nearly 3,000 wells, and the proper facilities provided by appropriations, I expect to be able to analyze the larger part of this number during the present fiscal year, in addition to the other expected work. The principal object of these examinations of these wells being sanitary, bacteriological investigations should be included wherever the indications call for them."

And again, on page 215 of the Health Reports of the 18th Annual Report of the Health Commissioner for May 31st, 1895, there appears under the head "Wells Contaminated, total number of wells: total, 59 wells."

And again, on page 65 of the same report, there appears under the title "Wells:"

"Fifty-nine wells have been condemned by the Board of Health and very few have been closed. The standard which was established by the Board of Health in relation to wells should be legalized by the Municipal Assembly. Where city water is on any premises and where it is desired to retain the well for stock or washing purposes, a permit to do so should only be given under certain binding conditions."

And again, on page 66 of the 19th Annual Report of the Health Commissioner for 1895 and 1896, the following appears:

"A communication was submitted by the Health Commissioner in reference to the report of the City Chemist on analyses of the water from seven wells, the water of which is impure according to the standard adopted by the Board of Health

some two years ago. The communication was made the basis of the following resolution, which, on motion duly seconded, was adopted:

"'Resolved, That hereafter the City Chemist shall make no examinations of well or cistern water unless by special direction of the Health Commissioner." (6685 to 6688.)

In view of the fact that this large number of contaminated wells exists in the City of St. Louis, and in view of the fact that an examination of these wells which had been found by the City Chemist, Dr. Teichmann, to be polluted, and notwithstanding this fact the examination for the condemnation of these wells was stopped by the Board of Health, the fact remains that these four or five thousand wells existing in the City of St. Louis in a contaminated state is an immediate, present and continuous danger and menace to the citizens of St. Louis.

IX.

THE EVIDENCE IN THIS CASE ESTABLISHES AFFIRMATIVELY BEYOND ALL QUESTION, THAT THE NUMBER OF DEATHS UNDER THE HEADING OF TYPHOID FEVER IN THE PUBLISHED REPORTS OF THE BOARD OF HEALTH OF THE CITY OF ST. LOUIS, AND AS EMPLOYED AND USED BY THE COMPLAINANT IN THIS CONTROVERSY TO ESTABLISH THEIR CASE THAT TYPHOID FEVER HAS INCREASED IN THE CITY OF ST. LOUIS SINCE JANUARY, 1900, DO NOT CORRECTLY SHOW THE TRUE TYPHOID CONDITIONS EXISTING IN THE CITY OF ST. LOUIS SINCE 1900, OR THE TYPHOID CONDITIONS THAT OBTAINED IN ST. LOUIS PRIOR TO 1900, FOR THE REASON THAT IN THE PUBLISHED REPORTS OF THE BOARD OF HEALTH OF THE CITY OF ST. LOUIS THERE APPEARS A COLUMN OF NONDESCRIPT FEVERS CHARACTERIZED UNDER THE NAMES OF INTERMITTENT, REMITTENT, TYPHO-MALARIA, CONGESTIVE AND SIMPLE CONTINUED FEVERS, AND UNDER THIS HEADING THERE APPEARS A DEFINITE NUMBER OF DEATHS ATTRIBUTED TO THESE VARIOUS FEVERS, AND THE EVIDENCE IN THIS CASE ESTABLISHES BEYOND ANY QUESTION, THAT THESE NONDESCRIPT FEVERS ARE, IN REALITY, MAINLY TYPHOID FEVER AND SHOULD HAVE BEEN CLASSIFIED UNDER THE HEADING OF TYPHOID FEVER AND NOT CLASSIFIED SEPARATELY AS DISTINCT TYPES OF FEVER, AND THAT ONLY BY UNITING THE DEATHS REPORTED UNDER THE HEADING OF TYPHO-MALARIA, ETC., WITH THOSE REPORTED UNDER TYPHOID FEVER CAN AN APPROXIMATE JUDGMENT AS TO THE TRUE TYPHOID FEVER MORTALITY IN ST. LOUIS BE OBTAINED, THAT, WHEN PROPERLY COMPILED AND ANALYZED, THE TYPHOID FEVER STATISTICS OF THE CITY OF ST. LOUIS, AS SHOWN IN ITS PUBLISHED BOARD OF HEALTH REPORTS, DO NOT DISCLOSE ANY REAL INCREASE OF TYPHOID FEVER, OR AT MOST, A DOUBTFUL AND HALTING ONE, SUCH AS MIGHT BE EXPECTED IN A WORLD'S FAIR CITY, WITH A CONSIDERABLE

INFLUX OF POPULATION AND NUMEROUS AND CONTINUOUS SOURCES OF INFECTION. NO EXPLOSIVE OUTBURST OF TYPHOID FEVER, SUCH AS CHARACTERIZES WATER-BORNE EPIDEMICS, FOLLOWED THE OPENING OF THE CHICAGO DRAINAGE CANAL.

The complainant in this case relied solely upon the published Board of Health reports of the City of St. Louis in order to establish the typhoid conditions in the City of St. Louis, and selected from those reports the number of deaths reported under the heading of typhoid fever, which number of deaths is as follows:

1890	277	1897	125
1891	160	1898	95
1892	488	1899	130
1893	215	1900	168
1894	178	1901	198
1895	106	1902	222
1896	106	1903	288

(6903.)

In support of the foregoing statement we desire to quote Mr. Jeffries, the able and learned Assistant Attorney-General of Missouri, who had practically exclusive charge of this case from its inception to its conclusion, which statement made by Mr. Jeffries appears on page 6602:

Mr. Jeffries: "In answer to the counsel I will state that we accept the truthfulness of what is shown in the Board of Health reports from the deaths from typhoid fever, but that such deaths contained in the published Board of Health reports is the only statistics that were offered by the plaintiff."

Every witness who testified in this case on the part of complainant assumed that the foregoing tabulation of deaths from typhoid as the same occurred in the published Board of Health reports of the City of St. Louis correctly stated the typhoid conditions existing in that city prior to and since the opening of the Drainage Canal. Each one of the witnesses employed the published Annual Health Reports of St. Louis as authority

for the statistics which were introduced in evidence in this case. (See Dr. Ravold, 411; Teichmann, 1432; Sedgwick, 2294-2335; Fuller, 2610.)

Basing their conclusions upon the fact that the typhoid fever mortality in St. Louis was correctly disclosed by the foregoing table of deaths, they testified that typhoid fever had increased in the City of St. Louis since 1900 over conditions which obtained prior to that time, and that such increase was due to the opening of the Drainage Canal on January 17th, 1900. The testimony in this case shows that about the time that the Drainage Canal was about to be completed the opening of said canal was being agitated in the public press of St. Louis. This resulted in a considerable discussion. An investigation was going on at that time of analyses of the samples of water collected, and was attracting considerable attention. A circular letter was issued by the Health Commissioner and sent to the physicians of St. Louis calling the attention of physicians to the fact that the law required them to report all cases of typhoid and all deaths from typhoid promptly. (See Teichmann's testimony, pp. 1439, 1440, Vol. 2.)

The effect of this letter sent by the Commissioner of Health of St. Louis to the physicians practicing medicine in that city, is manifest in the mortality reports under the heading of typhoid fever. A careful investigation of the mortality statistics as published in the Public Health Reports of the City of St. Louis disclosed the fact that there were two columns of fever under which a definite number of deaths were reported. In one column appears typhoid deaths, and in another column under the heading of intermittent, remittent, typho-malaria, congestive and simple continued fevers, appears a definite number of deaths attributed to these various fevers; and by a comparison of the number of deaths reported under typhoid with those reported under typho-malaria, etc., the increase since 1900, under the typhoid death column, is followed by a decrease in the typho-malaria column. This remarkable state of facts as disclosed by the mortality statistics in the published Health Re-

ports of St. Louis led the defendants to inquire what were intermittent, remittent, typho-malarial, congestive and simple continued fevers. Are they distinct types of diseases so recognized and classified under these different headings, or are they terms employed by physicians who have made wrong diagnosis of typhoid fever or malarial fevers? These interrogatories addressed themselves to the consideration of the defendants in this case for solution. With that object in view the defendants selected the most eminent doctors that could be found in the universities of this country, and who have made a specialty of typhoid and malarial fevers. They went to Johns Hopkins University, the University of Michigan, the University of Chicago, and selected men who were known and recognized as pre-eminently qualified to express an opinion upon the character of the diseases named and classified in the published reports of the Board of Health of the City of St. Louis under the names of intermittent, remittent, typho-malarial, congestive and simple continued fevers.

Dr. William S. Thayer, of the Johns Hopkins University, associated there with such men as Dr. William H. Welch and Dr. Osler; also Professor Victor C. Vaughan and Professor George Dock, of Ann Arbor, Michigan, who were selected by Surgeon General Sternberg, of the United States Army, to visit the fever stricken camps of Chickamauga, Jacksonville and Montauk Point during the Spanish-American War; Dr. Lewellys F. Barker, of the University of Chicago, formerly of Johns Hopkins University, and who had been selected by the United States Government to investigate the bubonic plague in San Francisco, and by the Johns Hopkins University to go to the Philippines and investigate a disease there known as beri beri; Dr. Ludwig Hektoen, Professor H. L. Russell, of the University of Wisconsin; and also Professor E. O. Jordan, of the University of Chicago, were called by the defendants in this case and testified that there was no disease known and recognized by the medical profession as intermittent, remittent, typho-malarial, congestive and simple continued fevers; that the terms were

misnomers for either typhoid fever or malaria, and as malaria had no such mortality as that disclosed by the Board of Health Reports of St. Louis under typho-malaria, that the great proportion of deaths from these nondescript fevers properly belonged under the heading of typhoid deaths. And it is a significant fact that not a single physician has been called and placed upon the witness stand by complainant to contradict these eminent men or show that they were mistaken. But on the contrary, their position is sustained by several of complainant's witnesses who were called to testify in this case.

Defendants in this case, in support of their contentions as above indicated, submit in part the testimony given upon this subject.

Professor E. O. Jordan, who prepared the statistics from the St. Louis Board of Health reports which were considered by the other witnesses who testified in this case, testified upon this subject in part as follows:

"Q. Have you made a special study of the so-called germ diseases?

"A. Yes, sir, in connection with my work in bacteriology I have had to study a number of the so-called germ diseases with considerable care.

"Q. Do these diseases caused by germs come within the scope of your study?

"A. Yes, sir; it is generally conceived that the scope of bacteriology to-day includes the various diseases due to germs of various kinds, those closely related to bacteria as well as to bacteria themselves. I refer especially to the so-called protozoan diseases, of which malaria is a type. The malaria germ is not a bacterium properly speaking, but a protozoan. Malaria is, however, one of the germ diseases and is studied and investigated by bacteriologists.

"Q. Will you distinguish between a protozoan and a bacterium?

"A. A protozoan is a one-celled animal; a bacterium a one-celled plant. The protozoa are of a more complicated struc-

ture than the bacteria and possess as a rule more intricate life histories. Protozoa are the lowest members of the animal series, as bacteria are the lowest plants known.

"Q. What studies have you made upon typhoid fever and malaria fever from the standpoint of a bacteriologist?

"A. I have examined the organisms of these diseases and have made blood examinations from cases of typhoid fever and malaria and have examined the literature with reference to the geographical distribution, fatality and general character of these diseases.

"Q. In connection with such study as you have detailed, does that lead you into the question of the proper diagnosis of the fevers, the kinds of typhoid and malaria?

"A. Yes, sir, that has become a very important question in bacteriological laboratories in the last few years. It is now generally recognized that a very important and perhaps the most important means of distinguishing between typhoid fever and malaria is by examinations made in the laboratory.

"Q. Have you had any experience with the diagnosis of these fevers?

"A. Yes, sir, I have examined and caused to be examined blood coming from patients suffering from these diseases.

"Q. Have you studied these questions sufficiently to give an expert opinion upon them?

"A. I think that I have.

"Q. What is typhoid fever and its clinical diagnosis?

"A. The symptoms of the disease known as typhoid fever are quite various, but the disease is characterized ordinarily by certain well marked peculiarities, such as the temperature curve with its gradual step-like ascent, until the height of the fever is reached, and then its gradual step-like decline. The onset of typhoid fever is often marked by a severe headache, although this symptom may be absent. There is often abdominal pain and tenderness. In a considerable proportion of cases, over 70 per cent., I believe, rose spots appear on the abdomen. These spots are due to typhoid bacilli in the skin

where the spots become reddened. This is a specific eruption due to typhoid bacilli in those cases.

"Epistaxis is not an uncommon symptom in this disease. In most cases of typhoid fever a few days after the onset of the attack an examination of the blood by what is known as the Widal test affords a highly characteristic mark of the disease and is one of the most important diagnostic features. The blood of patients suffering from genuine typhoid fever responds positively to this test, while the blood of well persons or persons suffering from other diseases than typhoid fever gives as a rule negative results.

"Q. What is malarial fever and its clinical diagnosis?

"A. There are three well recognized types of malarial fever, due to three different kinds of parasites. These different types of fever are characterized by a difference in the periodicity of the well known malarial paroxysm. In the tertian type of malarial fever the parasite completes the cycle of its development every forty-eight hours. The onset of the paroxysm coincides with the sporulation of the parasite and the disintegration of the blood corpuscles that accompanies this process. The tertian form of malarial fever is much more common in the temperate zone than either of the other phases. It is rarely, if ever, fatal in its uncomplicated form.

"The quartan malarial fever is caused by a parasite very similar to the tertian parasite, but completing its life cycle in seventy-two hours, instead of forty-eight. The malarial paroxysm occurs every third day instead of every other day, as is the case in the tertiary fever.

"Tropical malarial fever is caused by a parasite with a somewhat irregular cycle of development; the parasite of the tropical fever is not so commonly found in the circulating blood as the others, but carries out a large part of its life history in the internal organs, such as the spleen. This is the most serious of the three types of malarial fever. These parasites, the tertian, the quartan and the tropical parasite, can be recognized by a blood examination. The parasites, in each case,

invade the red blood corpuscles and pass through the various phases of their development ensconced in the body of the red blood corpuscles.

"Q. What is intermittent fever and its diagnosis?

"A. The term intermittent fever refers to that type of fever in which the temperature after being high for some time is intermitting and the temperature of the individual returns completely to the normal. The term is loosely used, but is applied oftentimes to various forms of malaria.

"Q. Is it a distinct type of fever?

"A. It is not.

"Q. What is remittent fever and its clinical diagnosis?

"A. The distinction between remittent and intermittent fever lies in the fact that the temperature does not return completely to normal in the remittent, but rises and falls.

"Q. Is remittent fever a distinct type of disease?

"A. It is not. The symptom of remittency may characterize various pathological conditions.

"Q. What is typho-malarial fever and its clinical diagnosis?

"A. The term typho-malaria fever as ordinarily applied in this country is used for fevers which may be either typhoid or malaria. Most of the cases of so-called typho-malaria are really cases of typhoid fever. It may rarely happen that a mixed infection occurs, that an individual is infected both with the bacilli of typhoid fever and with some one of the malarial parasites, but these cases are so rare as to rank as medical curiosities and have no far-reaching significance. Typho-malarial fever is not a distinct entity.

"Q. What is congestive fever and its clinical diagnosis?

"A. The term congestive fever is a vague term, comprising no definitely recognized type of disease. The symptom of congestion of various internal organs, such as the liver, is what has perhaps given rise to the use of this term.

"No such disease as congestive fever is recognized by the best physicians at the present day.

"Q. What is simple continued fever and its clinical diagnosis?

"A. The term simple continued fever is an old term in medicine which owes its origin to a period when methods of diagnosing diseases were not so far advanced as at present. As the name implies, it refers to a type of fever in which the temperature remains high for quite a long period. Most of the cases that would be likely to be reported as cases of simple continued fever at the present time are simply cases of mild typhoid fever.

"Q. Are intermittent fever, remittent fever, typho-malaria fever, congestive fever and simple continued fever distinct types of fevers and so recognized by bacteriologists and clinicians?

"A. Most of the affections designated by these different names are either typhoid fever or malaria, and these terms, mentioned in your question, are not generally employed at the present time as representing different and specific types of disease.

"Q. What epidemiological and sanitary significance are attached by statisticians to these fevers as above described, when they appear in vital statistics?

"A. It is generally considered that these designations relate in almost every instance to cases of typhoid fever, and that they should be so regarded.

"It is the general opinion among statisticians that the deaths so classified should be transferred bodily to the column of deaths from typhoid fever, since they are practically in all cases deaths from typhoid fever and not deaths from malaria. Malaria, in fact, as it occurs in temperate countries, is rarely fatal.

"Professor William Osler, of Johns Hopkins University, in his article on malaria fever in Allbutt's System of Medicine, Vol. 3, page 738, states:

"'Unfortunately, for many years and in many regions practitioners have been in the habit of labeling as malaria every

instance of obscure disease in which they could not make a diagnosis, so that the vital statistics are falsified in a remarkable manner. In the United States Census Report for 1890, which covers the six preceding years, the deaths from malarial fever in New York and Brooklyn were more numerous than from typhoid fever. In both these cities it is notorious that a death from true malaria is a great rarity, not more than three or four cases occurring each year in the entire hospital practice of the City of New York.

"'In the regular forms of malarial fever the death rate is very slight, and results usually from complications, such as acute nephritis.'

"In the testimony of Dr. William C. Woodward, who has already testified in this case, page 4602, I find the question:

"'Q. In this table marked Exhibit 74, you have what is known as typhoid-malaria and typhoid fever. What is the difference between typhoid fever and typhoid-malaria?' The answer: 'I regard a case of typho-malaria fever as a case of typhoid fever, in which the physician has made a mistake at the beginning and called it malarial fever, and he seeks the best way to get out of the hole. We classify them separately because some people regard them as different diseases, and we furnish our statistics to people and let them use them as they see fit, but I have expressed my opinion.

"'There is a very marked distinction between malarial fever and the other diseases, unless you regard the typho-malarial fever as typhoid fever. When it comes to typhoid-malarial and typhoid fever the best authorities to-day, I believe, regard them as the same disease.'

"In a recent article by Dr. John S. Fulton, Health Officer of Baltimore, Maryland, entitled, 'Typhoid Fever,' and appearing in the Journal of the American Medical Association for January 9, 1904, this matter of the relation between typhoid fever and malaria is exhaustively discussed, with a very full statistical presentation. On page 74 of this article is given a series of charts, showing the typhoid mortality and the re-

puted malaria mortality in different sections of the United States. These charts show the malaria curve below the line reflects the typhoid curve above as faithfully as the shores are reflected by the surface of a lake, the seasonal apex of the groups corresponding.

"Dr. Fulton states his own opinion as follows:

"'My personal belief is that fatal malaria intoxication does not happen to one citizen a year in Maryland, though malaria is in some parts of the State a considerable cause of disability.'

"Then again: 'Of all the mortality charged in the South to malaria, death perhaps is due to typhoid fever. The United States Army experience would indicate that not more than half, in fact, is due to typhoid, and certainly more than 50 per cent. of the mortality so charged is not due to malaria. In the North a much larger part, probably two-thirds of the reputed malarial mortality, represents unrecognized typhoid.

"'Outside of certain well known areas, malaria does not kill citizens of the United States, and within those areas where malaria is a cause of grave sickness, its right to be considered an important cause of death has not been subjected to the rigid scrutiny which its apparent importance demands.

"'Speaking for that part of the United States that I know best, I can say that the terms "malarial" and "typho-malarial" express no definite belief as to the cause or character of a disease, but are applied to fevers of indeterminate nature.'

"It is my opinion that these statements represent correctly the prevailing judgment regarding these designations of intermittent fever, etc., used in mortality records. The great majority of the deaths so reported are due to typhoid fever.

"Q. Dr. William C. Woodward, whom you quoted, is the health officer of the District of Columbia, is he not?

"A. I believe that he is.

"Q. Does the number of deaths reported as occurring from typhoid fever in the City of St. Louis, according to the reports of the St. Louis Health Department, represent in your

opinion the total number of typhoid deaths actually occurring in that city from the period of 1890 to 1903, inclusive?

"A. They certainly do not.

"Q. What reasons have you for stating that they do not?

"A. I find in the records of the Health Department of the City of St. Louis a very considerable number of deaths under the heading remittent, intermittent, typho-malarial, congestive and simple continued fevers. I have already given what seems to me adequate reasons for believing that the majority of these, if not indeed all of them, were deaths from genuine typhoid fever and properly should be so classed.

"Q. To what do you attribute the failure of these statistics to properly disclose the number of typhoid fever deaths occurring in the City of St. Louis?

"A. Since there is, in my opinion, no question that a number of deaths reported under the head remittent, intermittent, typho-malarial, congestive and simple continued fever were undoubtedly deaths from typhoid fever, and since there is no precise method of determining just what proportion of these deaths were actually deaths from typhoid fever, it is certainly difficult, if not impossible, to determine how many typhoid fever deaths actually occurred in St. Louis during the given year, particularly since the number of deaths recorded under the heading remittent fever, etc., is so very large in St. Louis.

"Since there is no reason to suppose that these figures do not correctly represent the reports received from the physicians of St. Louis, I see no escape from the conclusion that the value of these statistics to properly disclose the number of typhoid fever deaths occurring in St. Louis was due to an improper diagnosis.

"Q. Why is it that doctors will apply the terms remittent, intermittent, typhoid-malarial, congestive and simple continued to fevers that are recognized as being typhoid or malaria?

"A. These terms that you mentioned have the weight of traditional use behind them. Furthermore, it is only in relatively recent years that the sure distinction and differentiation

of typhoid and malarial fevers has become possible, through the application of laboratory methods. Many of the physicians who received their medical education before these laboratory methods were in vogue do not habitually employ such methods in their practice, and without these modern methods, on the basis of clinical symptoms alone, it is often difficult and indeed well nigh impossible to differentiate obscure and indefinite types of fever.

"Q. Do you know of any city in the country where the death rate from malaria alone is as high as in the City of St. Louis, as evidenced by the Board of Health reports of that city?

"A. No, sir, I do not. In my opinion no city in the United States has as large a death rate from genuine malaria as would be indicated by the official records of St. Louis, assuming that all deaths reported under this head of remittent, intermittent fever, etc., were deaths from malaria.

"Q. What do the malaria statistics show in cities where careful attention has been paid to malaria fevers?

"A. In the City of Baltimore, where particular attention has been paid to the study of malaria and typhoid fever and their diagnosis, at the Johns Hopkins University Medical School, the effect of such study is shown in the relatively small number of deaths reported from malarial and typhoid-malarial fevers.

"I may say that it is the practice in that city to class the deaths reported from typho-malarial with the deaths from typhoid fever, rather than with malarial. This seems to be an indication that the health authorities of that city are convinced that the deaths reported by physicians as occurring from typho-malarial are in reality cases of typhoid fever.

"Q. Is it generally recognized by sanitarians and epidemiologists that classifying typhoid fever in one column and remittent, intermittent, typho-malaria, congestive and simple continued fevers in another column in Board of Health reports is an improper classification from a scientific standpoint of

view, as affording a true indication of the prevalence of typhoid fever and malaria?

"A. In my opinion the classification is so recognized. A truer indication of typhoid fever mortality would be obtained by adding the deaths reported under the miscellaneous headings to the deaths reported as occurring from typhoid fever. This confusion of the records of vital statistics is, of course, especially liable to occur in those districts where malaria is prevalent and where a faulty diagnosis on the part of the attending physician is more liable to occur.

"Q. Have you compiled from the Board of Health Reports of the City of St. Louis a table showing the typhoid deaths by each month from 1895 to 1903, inclusive, with a table for the same period with fevers indicated at the heading, remittent, intermittent, typho-malarial, congestive and simple continued fevers?

"A. I have.

"Q. Will you produce and read into the evidence the compilations which you have made?

"A. It is as follows:

St. Louis.

	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
	1895.		1896.		1897.		1898.		1899.	
January	12	10	4	13	7	7	4	6	10	4
February	3	7	4	10	9	5	6	10	7	8
March	3	8	3	6	7	11	7	9	4	6
April	7	7	4	11	4	13	6	8	5	6
May	6	9	9	10	7	8	2	8	2	12
June	6	14	6	7	9	18	7	10	5	8
July	9	8	13	23	10	17	9	13	9	18
August	17	15	29	34	18	20	(9	14)	6	30
September	9	32	13	27	17	31	14	18	16	28
October	15	24	9	20	17	24	12	12	15	16
November	13	8	7	14	15	13	7	13	32	8
December	7	13	5	2	5	5	12	13	20	4

A. Typhoid Fever.

B. Remittent, Intermittent, Typho-malarial, Congestive and Simple Continued Fever.

St. Louis.

	1900.		1901.		1902.		1903	
	A.	B.	A.	B.	A.	B.	A.	B.
January	19	6	8	5	14	5	15	4
February	5	3	14	0	16	6	15	1
March	16	9	11	4	11	9	20	4
April	4	7	4	7	14	3	17	4
May	4	7	8	7	11	8	15	8
June	8	12	6	9	7	4	18	8
July	15	9	13	15	14	12	27	10
August	20	20	31	5	26	7	37	10
September	13	20	24	9	21	16	42	17
October	30	9	32	11	32	17	29	17
November	15	3	27	5	31	9	24	3
December	19	7	20	3	25	6	31	5

A. Typhoid Fever.

B. Remittent, Intermittent, Typho-Malarial, Congestive and Simple Continued Fever.

"Q. Will you state what this table shows?

"A. This table shows the deaths in St. Louis by months from January, 1895, to December, 1903, inclusive, recorded under the headings A typhoid fever, B remittent, intermittent, typho-malarial, congestive and simple continued fevers.

"The table shows a close parallel between the number of deaths reported from these two causes. In the months of July, August, September and October the number of deaths reported under both of these headings is high, while in the months of April and May it is on the whole low.

"An interesting change is noted in the latter part of this table. For the first five years of the table the number of deaths under the heading B (remittent fever, etc.), was greater than the number of deaths under the heading A (typhoid fever). Beginning with 1901 the reverse is true. The number of deaths reported under the heading Typhoid Fever becomes greater than the number reported under the heading Remittent Fever. To take, for example, the month of September:

	A (typhoid fever).	B (remittent fever, etc.).
1895	9	32
1896	13	27
1897	17	31
1898	14	18
1899	16	28
1900	13	20
1901	24	9
1902	21	16
1903	42	17

"Inspection of these figures shows that in the last four years there has been a transfer from the column B, that of remittent fever, etc., to the column A, that of typhoid fever, the effect being to diminish the number of deaths reported as remittent fever, etc., and increase those reported as typhoid fever.

"Q. Have you prepared a table from the Board of Health Reports of the City of St. Louis for the years 1900 to 1903, inclusive, showing the number of deaths reported in the typhoid column, the number of deaths in the remittent, intermittent, typho-malarial, congestive and simple continued fever column, and the added totals of these two columns for the period above mentioned?

"A. I have.

"Q. By whom was the table that you have already read in evidence and the one that you now have prepared, and from what source was the information taken that is contained in the table?

"A. These tables were prepared by me personally, and the information upon which they are based was obtained from the official reports of the Health Department of the City of St. Louis.

"Q. Will you read the table last described by you in evidence?

"A. It is as follows:

St. Louis.

(Population 1900, 575,238.)

YEAR	Typhus Typhoid Fever.	Reported Deaths from Remittent, Intermittent, Typho-malarial, Congestive and Simple Continued Fevers	Total
1890	140	226	361
1891	165	216	381
1892	441	326	767
1893	215	284	499
1894	171	179	350
1895	107	155	262
1896	106	177	283
1897	125	172	297
1898	95	134	229
1899	131	148	279
1900	168	112	280
1901	198	80	278
1902	222	102	324
1903	288	91	379

"Q. State what the table you have just read in evidence shows.

"A. This table shows a similar condition to that evidenced in the table of monthly deaths just produced. The total number of deaths per year reported under the heading typhoid fever and under the heading remittent fever, etc., are given in this table.

"They show that a much larger proportion of deaths is recorded under the heading remittent fever, etc., before the year 1900 than since that year.

"They also show that whereas the number of deaths reported from typhoid fever was generally less during the first ten years of this period than the number of deaths reported from remittent fever, etc., during the last four years, the case has been just reversed. It is evident that there has been some

cause or that there have been some causes at work tending to produce a more accurate diagnosis on the part of the physicians, and that a larger number of cases of true typhoid fever have been recognized as such during the latter period than during the earlier one.

"Q. Professor Teichmann testified (page 2336 of my transcript of the record) that two circular letters, 'one issued in the fall of 1900 and another issued in the fall of 1901,' were 'issued by the Health Commissioner of St. Louis, calling the attention of physicians to the fact that the law required them to report all cases of typhoid and all deaths from typhoid,' and at the time that letter was sent out the question of opening the Drainage Canal was being agitated in the public press of St. Louis, and there was considerable discussion, 'and an investigation was going on at that time of the analyses of the samples, etc.,' and that attracted considerable attention. From your examination of the statistics of St. Louis for the years 1900, 1901 and 1902, as compared with previous years, does the effect of such a letter as testified to having been sent to the doctors of St. Louis by the Health Department of St. Louis manifest itself in the statistics?

"A. It certainly seems reasonable to suppose that such a letter as that described in your question as having been sent to the physicians of St. Louis would have some effect upon their scrutiny of cases of fever, and that it might cause them to pay closer attention to diagnosis, and perhaps apply some of the modern methods of differentiating typhoid fever from conditions for which it might be mistaken.

"It is certainly in my opinion a significant fact that since 1900 there has been this decided change in the mode of reporting deaths.

"Q. In what way does the effect of such letters appear on the statistics?

"A. Beginning with the year 1900 the proportion of deaths from typhoid fever is much greater as compared with the deaths from intermittent fever than in the preceding decade.

This is just the effect that would be expected if the attention of the physicians had been specially directed to the diagnosis and differentiation of typhoid fever in its various forms, including obscure and mild cases.

"For the three years, 1899, 1900 and 1901, the total number of deaths reported from 'typhoid fever' and 'remittent fever, intermittent fever,' etc., is almost precisely the same, but the proportion reported from typhoid fever alone in 1900 and 1901 is much greater than in 1899.

"Q. From your examination of the typhoid and typho-malarial group (meaning to include in the latter those deaths reported under the head of remittent, intermittent, typho-malarial, congestive and simple continued fevers), what is your opinion as to whether these two tables taken separately correctly show the typhoid condition in the City of St. Louis for the period mentioned?

"A. It is my opinion that considering the number of deaths reported separately under the heading typhoid fever, that the total number of such deaths and the average number is not correctly represented by the tables reported under this head alone.

"Q. Upon what do you base your opinion that they do not correctly show the typhoid conditions in the City of St. Louis, taking them separately?

"A. I base my opinion upon all the facts that are known concerning the sources of error in the collection of vital statistics, the possibility of error in diagnosis in this group, the improvements in methods of diagnosis during the last few years, and the attention that has recently been specially focused upon this group of diseases.

"There is every reason to suppose that during the first five years covered by these tables a larger proportion of the deaths recorded under the heading 'intermittent fever, etc.,' were genuine typhoid fever than in the latter period, owing chiefly to the progress that has been made in the methods of diagnosis.

"Q. From your knowledge of the classes of fever men-

tioned in these two columns of vital statistics taken from the Board of Health reports of the City of St. Louis, how should they be treated by an epidemiologist and sanitarian in order to arrive at the true condition of typhoid fever in the City of St. Louis?

"A. That is a difficult question to answer, owing to the fact that during the latter portion of the period covered the conditions of record and diagnosis have not been strictly comparable with those in the early portion of this period.

"One way of attempting to arrive at the true typhoid mortality in the City of St. Louis during the period indicated would be by assuming that all the deaths recorded under the heading 'remittent fever, etc.,' were actually cases of typhoid fever, and should be added to those in the column of typhoid fever proper.

"Another method would be to assume that a certain proportion of the deaths reported from remittent fever, etc., say 50 per cent., were deaths from genuine typhoid fever, and that this 50 per cent. should be added to the deaths reported under the heading 'typhoid fever' alone.

"It is my opinion that the truth lies somewhere between these two extremes and that from one-half of the deaths reported from intermittent fever to all the deaths reported from this cause should be classed as genuine typhoid fever. The proportion undoubtedly varies somewhat from year to year, the number that should be transferred from one column to another probably being less in the last five years or six years than in the earlier period.

"On the whole it is my opinion that most epidemiologists and sanitarians would consider that a truer conception of the typhoid fever mortality in St. Louis would be derived by transferring all the deaths from the remittent, intermittent column, than by transferring only 50 per cent. of the deaths, but that is a matter of opinion simply.

"Q. Have you made any studies of comparisons between the typhoid and typho-malarial groups of the City of St. Louis with those of any other cities?

"A. Yes, sir, I have examined the deaths reported from malaria fever in the City of Chicago from 1851 to the end of 1902. * * * I have also examined the deaths reported from typhoid fever and those reported from malarial diseases in the City of Albany, by months, between January, 1891, and December, 1903.

"I have also examined the Baltimore figures, as I have already mentioned.

"Q. If so please state how they compare.

"A. There is the same general correspondence by months and years that has been noted in the St. Louis records. For example, the largest number of deaths reported from malarial fever in Chicago was in the year 1891, the same year when typhoid fever prevailed in epidemic form in this city, and caused the largest number of deaths ever reported from this cause.

"In general, when the deaths reported from typhoid fever are low those reported from malarial fevers are low, and vice versa.

"The proportion of deaths reported from malarial fever is lower in the last ten years than in the earlier portion of this period, owing in large part probably to progress in methods of diagnosis.

"A very interesting condition is revealed by the monthly deaths reported from typhoid fever and malarial diseases in the City of Albany, New York. As is well known, a sand filter was put in operation in Albany on September 6th, 1899. During the ten years, 1891 to 1899, inclusive, the total number of deaths reported from typhoid fever were 777, or an annual average of 86. For the four years since the filter was put in operation the total number of typhoid deaths has amounted to 106, or an annual average of 26 since the filter was opened, as against 86 preceding.

"An exactly similar decline is noticed in the number of deaths reported from malarial diseases. Prior to the opening of the filter the deaths reported from malarial fever amounted to 61, an annual average of 7. In the four years since the filter

was opened only two deaths in all have been reported from malarial diseases, or an annual average of one-half.

"The inference is plain that both reported causes of death, namely, 'typhoid fever' and 'malarial diseases,' have been affected by the opening of the filter, and the only conclusion that can be drawn is that the deaths reported as occurring from malarial diseases were really cases of genuine typhoid fever.

"The strict parallelism between the deaths reported from typhoid fever and malarial disease in St. Louis, in Chicago, in Baltimore and in Albany demonstrates conclusively to my mind that the confusion in diagnosis already set forth has existed in widely separated localities. This confusion, however, has been less marked in those regions where malaria is less prevalent, and where, therefore, physicians would be less likely to resort to it as an explanation of disease and death.

"Q. Have you a table of the death rates from typhoid fever in the City of St. Louis?

"A. I have.

"Q. From what sources did you obtain the data from which the table which you made was complied?

"A. The figures for population were obtained from the United States census report for 1890 and 1900, the population for the intervening years, being estimated by Farr's formula, as was also that for the years 1900 and 1903.

"Q. What is Farr's formula?

"A. Farr's formula is a formula well known to vital statisticians by means of which the increase of population may be estimated on the hypothesis that the population increases in geometrical progression.

"It has been found that this method gives results that closely approximate to actual conditions. It has been thoroughly tested in Europe and in this country.

"Taking the population as determined by the United States census as a basis, and assuming that the increase between these years has proceeded regularly and by geometrical progression, it is a simple mathematical process to determine the population for each year between the two census years.

"Q. Upon what did you make the basis of compilation in the tables that you have prepared?

"A. I have estimated the death rate per 100,000 inhabitants based upon the figures of population obtained in the way just described under three heads, namely: For typhoid fever alone as tabulated in the health reports of the City of St. Louis; for typhoid fever plus 50 per cent. of the deaths recorded under remittent fever, intermittent fever, etc., and for typhoid fever plus all the deaths recorded under the head remittent, intermittent fever, etc.

"Q. Will you read into evidence the tables which you have prepared?

"A. Yes, sir. They are as follows:

Typhoid Fever Death Rate.

St Louis.

Death Rate per 100,000.

YEAR	Population.	Typhoid fever alone.	Typhoid fever plus 50 per cent. of deaths recorded under heading intermittent fever, etc.	Typhoid fever plus all the deaths recorded under the heading intermittent fever, etc.
1890	451,709	30.0	56.67	81.2
1891	462,763	35.6	58.98	82.3
1892	474,077	93.0	127.40	161.7
1893	485,668	44.2	73.52	102.7
1894	497,565	34.3	52.24	70.3
1895	509,740	29.9	30.35	51.3
1896	522,225	20.2	37.37	54.1
1897	533,762	23.4	39.53	55.6
1898	548,590	17.3	29.53	41.7
1899	361,510	23.3	36.49	49.6
1900	575,238	29.2	39.07	48.6
1901	589,315	33.5	40.39	47.1
1902	603,736	36.7	45.21	53.6
1903	618,510	46.5	54.0	61.3

"Q. Please state what these tables show as to the death rate in the City of St. Louis from 1890 to 1903, based upon the percentage of population.

"A. They show a considerable difference in the death rate according to the number of deaths assumed to be deaths from genuine typhoid fever. Considerable variation is exhibited in the three columns during this period, owing to the transfer of reported deaths from the intermittent column to the typhoid column, as already referred to several times in my testimony.

"Q. Will you compare the death rate of typhoid fever in St. Louis from 1890 to 1899, inclusive, with that of 1900 to 1903, inclusive?

"A. Assuming that the deaths reported under the heading typhoid fever alone during this period were the only deaths that occurred from this disease in the City of St. Louis, the average annual death rate from 1890 to 1899, inclusive, as shown in the detailed table, excluding, however, the year 1892 as being a year of special epidemic prevalence, was 28.8. On the same basis the average annual death rate from 1900 to 1903, inclusive, was 36.5.

"Assuming that only one-half of the deaths recorded under the heading intermittent fever, etc., were deaths from genuine typhoid fever, the average annual death rate from 1890 to 1899, inclusive, excluding, as above, the year 1892, was 46.07. On the same basis the average annual death rate from 1900 to 1903, inclusive, was 44.67.

"Assuming that all the deaths reported under the heading intermittent fever, etc., were deaths from genuine typhoid fever, an assumption, which in my opinion is not very wide of the mark, the average annual death rate from 1890 to 1899, inclusive, excluding, as above, the year 1892, was 65.4.

"On the same basis that from 1900 to 1903, inclusive, was 52.1.

"On either of the latter assumptions the death rate from typhoid in the four years, 1900 to 1903, was distinctly lower than in the preceding decade, even when the year of maximum

typhoid prevalence in that decade is excluded from the estimation.

"Q. Assuming that all the deaths in the typhoid column and the typho-malarial column are typhoid, how does the period four years prior to 1900 compare with the period four years since 1900 as to whether there is an increase or decrease in the typhoid fever in the City of St. Louis?

"A. The annual death rate on this basis is almost exactly the same, being 52.2 for the period of four years prior to the opening of the canal, and being 52.7 for the period of four years since the opening of the canal. With these figures it would be impossible to assert that there has been either an increase or a diminution in the typhoid fever death rate in this period on the assumption just predicated.

"Q. Has typhoid fever increased or decreased in the City of St. Louis since 1909 over the conditions that obtained for the ten years prior to 1900 in the City of St. Louis?

"A. It is emphatically my opinion that the average death rate from typhoid fever in the City of St. Louis has been less in the four years beginning with 1900 than the average for the preceding decade, excluding in this comparison the epidemic year of 1892.

"Q. How does the typhoid fever death rate in St. Louis compare with the death rate in other American cities during this period?

"A. Regarding the typhoid fever death rate as reported in St. Louis, from the figures of typhoid fever alone the death rate is not very different throughout this fourteen-year period with the death rate in the City of Boston, omitting in this comparison the epidemic of 1892 in St. Louis. In Boston the average annual death rate from 1890 to 1902, inclusive, as taken from the official figures in the health reports in the City of Boston, was 29.7, while the death rate in St. Louis, as inserted in the column typhoid fever alone, during the fourteen-year period already mentioned, excluding the year 1892, was 31.1, or almost exactly the same as that in the City of Boston during that period.

"The water supply of Boston throughout this period has been regarded as being a fairly satisfactory municipal supply. In the City of Lawrence, Mass., before filtration was introduced, the death rate from typhoid fever averaged 120. The death rate in the State of Massachusetts from typhoid fever during the period of 1897 to 1902 was 40, or considerably higher than that in the City of St. Louis for the period just indicated. In 1894 the death rate in the City of Lawrence was 48, and in 1899 it was 33.

"Considering the real death rate in the City of St. Louis from typhoid fever to be represented by the death rate computed on the total of the two headings, typhoid fever and intermittent fever, the death rate in this city throughout nearly the whole period under consideration has been excessive and higher than ought to exist in a city provided with a pure water supply.

"Q. Is there any reason other than those you have given for supposing that the number of typhoid fever deaths in St. Louis is higher than that indicated by the figures recorded under heading typhoid fever alone?

"A. Yes, I think the fact that I have just instanced regarding the death rate in other American cities is a very strong reason for believing that the actual number of typhoid fever deaths in St. Louis is higher than that indicated under the heading typhoid fever alone. Knowing what I do of the source of the St. Louis public water supply, and of the character of the water-shed of the Missouri, Mississippi and Illinois rivers for some distance above the water intake, I should expect that a city supplied with a non-filtered surface water of the character of the Mississippi River water at the intake tower at St. Louis would give rise to a higher death rate from typhoid fever than is indicated by the figure under the heading typhoid fever alone in the St. Louis health reports. The death rate from typhoid fever in St. Louis as reckoned on the total of typhoid deaths and typho-malarial deaths is, in my opinion, much nearer what would be anticipated from a consideration of the character of the Mississippi River water than the death rate as reckoned from the so-called typhoid fever deaths alone.

"Q. Professor, from a careful analysis of the typhoid and the typho-malarial mortality statistics as they appear in the Board of Health reports of St. Louis, and your knowledge of the conditions that obtain in other cities using a water supply from a river, as well as all other sources of knowledge which you possess upon this question, what is your opinion as to whether there has been an increase in typhoid fever in the City of St. Louis since January 17, 1900, over the average typhoid conditions that prevailed in St. Louis for ten years prior to that time?

"A. In consideration of all the facts regarding the mortality of typhoid fever in the City of St. Louis during the period indicated that can be obtained from the official records as published it is my opinion that the average annual death rate from typhoid fever in that city has been lower for the four years, 1900 to 1903, than for the preceding decade, excluding the epidemic year of 1892.

"Q. Assuming the same conditions in the previous question, what is your opinion as to whether there has been an increase of typhoid fever in the City of St. Louis since January 17, 1900, down to 1903, inclusive, over the general typhoid conditions that prevailed in St. Louis for the four years prior to 1900?

"A. From the facts already cited, which embody all the information that I have been able to obtain, and from a critical analysis of the figures presented in the reports of the health department of the City of St. Louis, I conclude that there has been no increase in the annual death rate from typhoid fever in the City of St. Louis since January 17, 1900, as compared with the average annual death rate for the four years preceding 1900. As shown in my answer to a previous question, the death rate for these two periods, computed on the assumption that the typhoid fever deaths and the typho-malarial deaths should be considered as a whole, is almost exactly the same.

"What is your opinion based upon all the information and

knowledge that you have in regard to the typhoid conditions of the water sheds above the St. Louis intake at the Chain of Rocks as to whether the typhoid conditions that have prevailed in St. Louis since January, 1900, are due directly to the opening of the Chicago Drainage Canal, which took place on January 17, 1900, wherein the sewage of Chicago was emptied into the Desplaines and Illinois rivers?

"A. It is my best judgment based upon all the information of which I have become possessed that no portion of the typhoid fever mortality occurring in St. Louis since January 1900 can be attributed directly or indirectly to the opening of the Chicago Drainage Canal.

"Q. Are you acquainted with the typhoid conditions that obtain along the Missouri and Mississippi rivers above the intake of the St. Louis waterworks, as well as those that obtain along the Illinois, the conditions of typhoid in St. Louis and the conditions of typhoid fever in Chicago?

"A. I have already submitted the information that I possess regarding the typhoid conditions of Chicago and St. Louis. I have here tables showing the deaths reported from typhoid fever in the principal cities on the Mississippi River above Grafton, the Missouri River and the Illinois River for the years 1893 to 1902, inclusive.

"Q. Is there any connection, in your opinion, between the typhoid condition that has prevailed in St. Louis since the opening of the Drainage Canal and the discharge of the sewage of Chicago through the Drainage Canal since January 17, 1900?

"A. In my opinion no such connection exists."

(See Jordan, Vol. 7, pp. 6284 to 6310.)

Professor H. L. Russell, of the University of Wisconsin, testified upon this subject, and his testimony in part is as follows:

"Q. Have you made a study of the so-called germ diseases?

"A. In connection with my studies on bacteriology, it has been necessary for me to make special studies of the various

germ diseases caused by bacteria and other lower forms of life.

"Q. Do these diseases caused by germs come within the scope of your study?

"A. Many of the diseases of man and animals of a transmissible nature are caused by the injection of parasitic organisms belonging to bacteria, and hence in the work of bacteriology consideration of these diseases and the diseases under which they are introduced is properly within the scope of my study.

"Q. Have you made any study upon typhoid fever and malarial fever from the standpoint of the bacteriologist or clinician?

"A. From the bacteriological point of view it has been possible for me to make a study of the diseases of typhoid fever and malaria, and the organisms which are known to possess a causal relation to those diseases.

"Q. In connection with your study as you have detailed, have you taken up the question of the proper diagnosis of fevers known as typhoid fever and malaria?

"A. In connection with such studies it is absolutely necessary, in order to make a proper diagnosis of such fevers, to take up the study from the laboratory point of view, and determine by examination of the blood whether the disease causes a reaction or not, and in connection with such studies I have performed these tests.

"Q. Have you had any experience in the diagnosis of these fevers, either in the laboratory or at the bedside?

"A. In connection with my studies of these diseases, and also in connection with routine work of the diagnostic laboratory with which I am connected, I have had experience in the study of these diseases and their diagnosis.

"Q. Have you studied these diseases sufficiently to give an expert opinion on them?

"A. In connection with the diseases previously mentioned this experience has been sufficient, together with the study of

the literature relating to this subject, to warrant me in giving an opinion as to whether diagnoses of typhoid fever or malaria are correct or not.

"Q. What is typhoid fever in its clinical diagnosis?

"A. Typhoid fever is a disease which is confined to man, and is widely distributed throughout the temperate zone. The symptoms of the disease are not always specific, but in general it is characterized by the production of fever, which often begins in a relatively obscure manner, the temperature rising from day to day until it reaches its maximum, and then gradually declining. The symptoms of the disease most frequently noted are headache, sometimes with more or less tympanitis, the production of rose-colored spots on the abdomen, which, however, in some cases do not appear, the enlargement of the spleen, accompanied sometimes with tenderness, and frequently copious bleeding at the nostrils. The lesions of the disease are usually manifested in the intestines, affecting Peyers patches and the solitary glands, causing an ulceration sometimes through the intestinal wall which may result in the production of a secondary complication of peritonitis.

"Q. What is intermittent fever and its clinical diagnosis?

"A. Intermittent fever, so-called, is a fever which is characterized by a marked variation in the temperature where it falls to a normal after a rising temperature and then a subsequent rise again, which is followed the next day by a fall.

"Q. What is remittent fever and its clinical diagnosis?

"A. Remittent fever, so-called, is one of the older expressions which is used to designate a type of fever in which the variation in temperature does not fall to the normal, but which is marked by frequent and rapid oscillations in temperature.

"Q. What is typho-malarial fever and its clinical diagnosis?

"A. Typho-malarial fever is again one of those older designations which is used to designate a type of fever and is employed to include many low types of fevers that with the better diagnostic means which are now available, especially since the

introduction of the Widal test for typhoid fever, can usually be differentiated into genuine typhoid or genuine malarial fever. Rarely does it happen in communities where both of these fevers are universally present that the organisms capable of producing these specific distinct diseases are found in the same case simultaneously.

"Q. What is congestive fever and its clinical diagnosis?

"A. Congestive fever again is an indefinite term applied to low fevers that have no well-marked characteristic. Its most marked symptom is more or less acute congestion. It has no accurate clinical significance as applied to any specific disease.

"What is simple continued fever and its clinical diagnosis?

"A. The type of fever in which the course of the febrile changes is more or less continuous. It has no marked characteristic symptoms.

"Q. Are remittent, intermittent, typho-malarial, congestive and simple continued fevers distinct types of diseases and so recognized by bacteriologists and clinicians?

"A. The terms remittent, intermittent, typho-malarial, congestive and simple continued are relics of old methods of description which attempted to differentiate these febrile changes merely on the basis of the symptoms which are most evident. They are not recognized by working bacteriologists or clinicians of the present time as being satisfactory names for specific types of fevers.

"Q. What significance do you attach to these terms as applied to fevers where they appear in vital statistics?

"A. The use of the terms remittent, intermittent, typho-malarial, congestive and simple continued as applied to vital statistics collected under present day conditions would, in my judgment, indicate that the causes of deaths were not classified as they should be, and would therefore lead one to place less reliance on such statistics than would be the case if they were more accurately classified."

"From the study of the statistics mentioned in the foregoing question and from the general knowledge of the relation which

these diseases bear to each other and the liability of making an improper diagnosis between them, I do not consider that the number of deaths reported in the vital statistics of the Board of Health of the City of St. Louis for the years 1890 to 1903, inclusive, represent the total number of deaths from typhoid fever which actually occurred in that city in that interval.

"Taking into consideration the fact, which is well recognized by sanitarians, that fevers classified under the heads of remittent, intermittent, typho-malarial, congestive and simple continued are in a large measure found to be fevers which, by means of modern diagnostic methods, would be recognized as typhoid fever, it is my opinion that the statistics, which include a large proportion of fatalities as due to fevers of this class, do not represent the true condition which obtained in that city with reference to the total typhoid death rate.

"In my judgment, the value of the statistics assumed in the hypothetical question rests in a large measure on the more or less imperfect diagnosis which has been made by physicians reporting those deaths to the city Health Department.

"Inasmuch as many practicing physicians are not personally familiar with modern diagnostic methods which are now employed in the most advanced practice with the diagnosis of typhoid fever and malaria, and the differentiation of one from the other, it frequently follows that the old expressions based upon the symptoms of the fever, which used to be used, are frequently used at the present time by such physicians when reporting the cause of death. Moreover, it frequently occurs that symptoms noted in cases of fever are not sufficiently distinctive to enable a physician to recognize with certainty whether he is dealing with genuine typhoid fever or malaria, and, consequently, owing to the tendency to retain these old terms in the descriptions of diseases, it naturally follows that many of the typical cases, which are more or less obscure in their symptoms, are reported in the cause of death as remittent, intermittent, typho-malarial, congestive and simple continued fevers.

"Inasmuch as the death rate from such malarial fevers as

occur in the United States of America is comparatively insignificant (there being practically no pernicious or tropical malaria, which is exceedingly fatal in this country except where imported), it of necessity follows that no city has as high a death rate from pure malaria alone as is represented in the number of deaths reported in the St. Louis statistics and included in the terms intermittent, remittent, typho-malarial, congestive and simple continued, which are assumed in the foregoing hypothetical question.

"In my opinion, it is practically impossible for any one to give an accurate idea as to what percentage of the deaths reported under the heading remittent, intermittent, typho-malarial, congestive and simple continued, assumed in the hypothetical question as occurring in the City of St. Louis, inasmuch as a majority of the cases terminating fatally are now diagnosed as typhoid fever, it is undoubtedly true that a large proportion of these deaths so reported should be classed as typhoid fever.

"Owing to the fact that the disease of malaria as it exists in the United States is a disease resulting in an exceedingly low mortality, it is undoubtedly true that the number of cases reported in the foregoing hypothetical question which should be classed as genuine malaria, is exceedingly small. This opinion is based upon the fact that the hospital records in Southern cities where malaria is more or less abundantly prevalent, and where modern methods of diagnosis are widely used for the recognition of the disease, show that the fatality from this disease is so small as to be practically negligible.

"In regions where malaria is known to frequently exist, and where the best modern methods of diagnosis are widely employed, it is noteworthy that the number of deaths reported as due to genuine malaria fever have been greatly reduced since the introduction of these methods. The results of this character are shown directly by the history of malarial cases which have been recorded in the Johns Hopkins Hospital, situated in Baltimore, Maryland. Malaria used to be very frequently re-

ported as the cause of death in the city, but, with the introduction of the methods of making blood examinations, the number of cases now reported show that the total number of deaths has been reduced to a mere fraction of what used to be reported.

"Inasmuch as modern methods of diagnosis have enabled the clinician to classify a larger proportion of specific febrile causes under the heads of typhoid fever and malaria, which, in former years, before the introduction of these methods, were generally classified and based on symptoms of the disease under the heading intermittent, remittent, typho-malarial, congestive and simple continued, it is well recognized by bacteriologists and clinicians that the continuation of the use of these traditional terms is merely to describe the symptoms of the diseases, that indicate their specific character, and is an improper classification from the scientific standpoint, and that where such a classification is followed, it is no true indication of the mortality which exists with reference to typhoid fever and malaria.

"In view of the fact that the mortality from genuine malaria in the United States is exceedingly small, it is considered that a large number of deaths which are reported in the reports of the Board of Health of the City of St. Louis in the year 1895 and 1903 and designated as B, in that table, must include, in addition to the exceedingly small number of deaths which are caused by the type of malaria which prevails in the United States, and, inasmuch as the fevers which are most likely to occur are either malarial or typhoid fevers, and taking into consideration the low mortality which really occurs in malaria, I should consider that it was generally probable that a large proportion of these diseases which are designated for convenience as Column B, for the respective years, should be placed in a column which includes the reports of the fatalities due to typhoid fever.

"Assuming that by far the larger proportion of the deaths which are reported in the reports of the Board of Health of the

City of St. Louis, for the City of St. Louis, for the years covered in the foregoing question, under the head of intermittent, remittent, typho-malarial, congestive and simple continued fevers, were really deaths which are attributable to the disease of typhoid fever, and, therefore, should be added to the totals which were actually reported in that city for those years under the caption Typhoid Fever, and, taking into consideration the statistics presented in the foregoing question, I should consider that the said statistics do not show material alterations which could be deduced with certainty in the typhoid fever mortality of the City of St. Louis, from the years 1899 to 1903.

"Q. Assuming that two circular letters were issued in the fall of 1900, another one issued in the fall of 1901, by the Health Commissioner of St. Louis, calling attention of physicians to the fact that the law required them to report all cases of typhoid and all deaths from typhoid and at the time those letters were sent out the question of the opening of the Drainage Canal was being agitated by the public press of St Louis, and there was considerable discussion and investigation going on at that time in regard to the analyses of the samples so collected, etc., and was attracting considerable attention, from your examination of the statistics of St. Louis, as heretofore assumed in hypothetical questions heretofore asked you for the years 1901 to 1903, as compared with previous years, does the effect of such letter, assuming that the same had been sent to the doctors by the Health Commissioner of the City of St. Louis, manifest itself in these statistics?

"A. In comparing the statistics assumed in the foregoing hypothetical question, I should consider that such data did manifest itself in the statistics.

"Q. In what way does the effect of such letter appear from the statistics?

"A. Take the statistics as to the mortality from typhoid fever and the mortality from those diseases which are included in what we may call typho-malarial, in the column designated in the previous statistics as Column B, taking into considera-

tion the fact that such statistics show a marked diminution in the number of the cases reported in the typho-malarial column for the year 1900 and the year 1903, inclusive, and that for the same period a marked increase is noted under the head of deaths from typhoid fever. Further, taking into consideration the fact that circular letters were issued in the fall of 1900, and 1901, respectively, by the Health Commissioner of the City of St. Louis, calling the attention of physicians to the requirements of the law as to the reporting of all cases and deaths resulting from the disease of typhoid fever, it is evident from the data of the report that the issuance of these letters by the Health Department of the City of St. Louis to the physicians of that city does manifest itself in the statistics as reported.

"Q. From your examination of the typhoid and typho-malarial group of deaths as assumed in the foregoing hypothetical question, what is your opinion as to whether these two tables, taken separately, correctly show the typhoid conditions of the City of St. Louis for the period mentioned?

"A. If consideration is given to either of the columns designated typhoid and typho-malarial death reports as reported by the Board of Health of the City of St. Louis, it is my opinion that neither of these reports of the fatalities do express the actual typhoid mortality of the City of St. Louis, for the period mentioned.

"Q. Upon what do you base your opinion that they do not correctly show the typhoid conditions in the City of St. Louis, taking them separately?

"A. This opinion is based upon the fact that it is highly probable that a large majority of the cases reported in the column designated B, in the foregoing questions, really were cases of typhoid fever; and, further, taking into consideration the effect which would be produced by the issuance of letters mentioned in the foregoing questions, it would lead to a more correct diagnosis of the disease of typhoid fever and the report of the same under the caption of Typhoid Fever, I

should consider that the results as presented in the foregoing questions do not correctly represent the typhoid conditions which actually occurred if these tables are considered separately.

"Q. From your knowledge of these classes of fever mentioned in the foregoing columns in the statistics as heretofore assumed, how should they be treated by bacteriologists and clinicians and statisticians in order to arrive at the true typhoid fever mortality in the City of St. Louis?

"Owing to the liability to confusion which must of necessity exist from the use of old traditional terms which are descriptive more of the symptoms than the specific nature of the disease in question, and the direct liability of the confusion of these terms with that of typhoid fever, I should consider that from the standpoint of the bacteriologist, clinician or statistician, in order to get at the true typhoid mortality which would exist in the City of St. Louis, that it would be necessary to add to the statistics which they have reported as typhoid, a large proportion at least, if not practically all, of the cases which have been reported under the caption which has been designated in previous questions as Column B, to those figures in the given typhoid fever cases.

"Taking into consideration the fact that the circulars issued by the Board of Health of the City of St. Louis have unquestionably had their influence in increasing the accuracy of the typhoid statistics since the issuance of that circular in 1900, and that the great majority, if not practically all of the deaths reported before the year 1900 under the head of remittent, intermittent, congestive, typho-malarial and simple continued fevers were actually cases of typhoid fever, and, therefore, should have been included in any statistics which showed the total amount of typhoid fever in the City of St. Louis for that time, and assuming the accuracy of the compilations which have been made by Professor Jordan, based on the relative increase of population as determined by Farr's formula, when to the typhoid fever death rates there have been added from

50 to 100 per cent. of all recorded deaths which have been reported, under the head of remittent, intermittent, congestive, typho-malarial and simple continued fevers, and which, in my judgment, represent data showing the actual amount of typhoid fever which did occur for the periods mentioned much more correctly than is shown by consideration of the reported deaths, as reported in the Board of Health reports of the City of St. Louis under the caption of typhoid fever alone, I should consider that the actual number of typhoid deaths which have occurred in St. Louis since the year 1900 shows no increase over the death rate in that city from this disease for the period mentioned prior to that time, with the possible exception of the recognized epidemic which occurred about the year 1892.

"Taking into consideration the fact that the typhoid statistics alone, as reported in the Board of Health report, for the City of St. Louis, do not represent the actual conditions which occur in that city with reference to this disease, but that these statistics should be increased by a large proportion, if not all, of the deaths which are reported under the caption of remittent, intermittent, typho-malarial and simple continued fevers, and that when such additions are made for the period which is covered in the foregoing questions, and comparisons are instituted between the typhoid mortality in St. Louis, as modified by the additional deaths which should be computed in the typhoid statistics and now reported under other causes, when these statistics are compared with the typhoid mortality statistics in other cities where similar types of water supply are employed for municipal purposes, it is my opinion that these statistics show that there has been no increase in the actual number of typhoid deaths which occurred in the City of St. Louis from January, 1900, to 1903, inclusive, when the typhoid death rate for this period is compared with that which actually prevailed in the City of St. Louis for the period embraced between the years 1890 and 1900, inclusive.

"In the operation of natural courses running water undergoes processes of purification, and frees itself from pathogenic organisms in due course of time.

"Q. State your opinion, as an expert on water supplies for cities and towns, as to whether or not the water of the Mississippi River west of the center thread of the main channel of the said river, below the mouth of the Illinois River, and down to the intake tower of the St. Louis waterworks at the Chain of Rocks, is less valuable for drinking purposes and more liable to carry water borne disease, such as typhoid fever and cholera, now than it was before the sewage from the Sanitary District of Chicago was running into the Drainage Canal and through it into the Illinois River?

"A. If the typhoid organism is killed out in the Illinois River in the period of time which is less than the necessary time for the flow of the water from the sewers of Chicago to the City of St. Louis, and assuming that the destruction of the typhoid organism is an index of the destruction of pathogenic organisms in water, and on the basis of the experiments which have been previously detailed in which proof is adduced to show that the vitality of the typhoid organism is destroyed in a much less time than is necessary for the flow of water from Chicago to St. Louis, it is my opinion that the waters of the Mississippi River west of the center of the main channel of the said river and below the mouth of the Illinois River, down to the intake tower of the St. Louis waterworks at the Chain of Rocks, is not less valuable for drinking purposes and not more liable to carry water borne diseases now than it was before the sewage of the Sanitary District was run into the Drainage Canal and through it into the Illinois River." (6547 to 6560.)

Dr. Ludwig Hektoen testified upon this subject, in part, as follows:

"Q. Are remittent, intermittent, typho-malaria, congestive and simple continued fevers distinct types of disease and so recognized by pathologists, bacteriologists and clinicians?

"A. No, they are not.

"Q. What significance do you attach to these terms as applied to fevers when they appear in vital statistics?

"A. I think that in a large percentage of the cases they mean typhoid fever.

"Q. Assuming in the question the number of deaths from typhoid fever and the number of deaths from typho-malaria, etc., fevers, do the number of deaths reported as occurring from typhoid fever alone in the City of St. Louis properly represent, in your opinion, the total number of typhoid deaths occurring in that city?

"A. No, because of the large number of deaths recorded under the heading of remittent, etc. I attribute the failure of the number of deaths to properly represent typhoid conditions to the reason just given in answer to the previous question, viz.: that the number of deaths attributed to malarial fevers, so called, is, in my opinion, excessive, and that, of course, depends upon erroneous diagnosis by the physicians in St. Louis. This undoubtedly is the result of the teachings laid down from the early period where these different forms of diseases, especially typhoid and malarial diseases, were not distinguished from one another. I know of no city in the country having as large a death rate from malaria as reported in St. Louis. Malaria fever is not a prominent cause of death in this country.

"The columns of intermittent, etc., fevers, in my opinion, means that between 75 and 90 per cent. of those cases probably should be put in the typhoid column. The tables appear to show that until the year 1900 the number of deaths from remittent, etc., fevers is, on the whole, smaller than from typhoid fever. By adding the totals typhoid and typho-malarial group the figures do not appear to me to show any increase in typhoid fever mortality since 1899.

"The letter sent out by the Board of Health to the doctors manifests itself in those statistics; it would seem to appear in the prominent increase in the number of deaths from typhoid fever associated with a corresponding prompt decrease in the number of deaths from remittent, etc., and other fevers, and, in my opinion, taking the two groups of figures separately, they do not correctly show the typhoid condition, for the rea-

son that I believe that a large percentage of the tables include under intermittent, remittent, etc., fevers what really were deaths from typhoid fever, and I think they ought to be consolidated in order to arrive at the true typhoid fever mortality in the City of St. Louis. In my opinion, I think that the approximate truth could be arrived at by consolidating the two tables and then perhaps subtracting 10 per cent.

"By considering the tables together and the increased population in St. Louis, typhoid fever has decreased in the City of St. Louis since 1900. I arrived at this by studying the figures in the table, and they show that up to the year 1895, inclusive, the death rate from typhoid fever appears to be approximately 80 or 90 per cent., whereas, after the period 1896, up to the period 1900, it appears to be 50 and 55 per cent.; that is, the death rate appears to be between 50 and 55 per cent., and between 1900 and 1903 the death rate is about the same." (See Vol. 7, pp. 6704 to 6710.)

Dr. Lewellys F. Barker, of the University of Chicago, testified in part as follows:

"Q. Doctor, will you state what is remittent fever, intermittent fever, typho-malarial fever congestive fever and simple continued fever?

"A. Those are all clinical rather than pathological terms, and date back to the time when classifications had to be made on symptomatology rather than upon pathology and etiology.

"The remittent fever was the term given to a fever which had exacerbations and decline without reaching the normal, as a rule, while intermittent fever—

"Q. Without the temperature reaching normal?

"A. Without the temperature reaching normal. And intermittent was the term given where the temperature went up high and came down to the normal, then up high again and down to normal.

"Typho-malarial fever was a term given to cases which were believed to be by many a fever distinct from typhoid, and distinct from malaria, a fever which ran the course of typhoid,

but which had many symptoms resembling those of malaria, while congestive fever was a very vague term used in different ways by different clinicians and was usually associated with the idea of congestion of the head, rush of blood to the head, along with the fever, while simple continued fever was a term applied by, as a rule, the less well educated physicians, to mild forms of fever running over a considerable period, generally over more than ten days or two weeks. It was a term used by people who believed that such fevers were not typhoid and not malaria, but simple continued fever. They didn't know exactly what it meant. Now all of those terms are given up by good clinicians at the present time; there is no such thing as a remittent fever as a clinical entity any more. It is either typhoid or malaria or acute tuberculosis, or some other infection, and usually it is possible during life to determine that a case of so-called remittent fever, or intermittent fever in the same way, may be one of several diseases, perhaps. Most often what is designated intermittent fever is malarial fever, but cases of typhoid fever are often mistakenly designated as malaria, intermittent, etc. The congestive fever might be one of various things; sometimes it is typhoid and sometimes it is malaria. Sometimes it is something else.

"Simple continued fever may be typhoid. I think perhaps most often it is a mild case of typhoid fever. It may be something else. None of these terms would be used now by a skilled clinician.

"Q. What is your opinion as to the justification of including these under one head, as is done in the St. Louis health reports?

"A. Well, I think that under the circumstances the medical practitioners, trained, as they are, there is nothing for the Health Board to do but to include them as they do, under that heading at the same time—I mean the remittent, intermittent, typho-malarial, congestive and simple continued fever. Those reports are sent in by the physicians to the Board of Health as deaths from those causes, and the Board of Health cannot

very well do anything but tabulate them in that way. Of course, from what I have said, it is clear that, in my opinion, those cases are nearly all cases of something else, cases of some disease that could be diagnosed by skilled physicians—mostly typhoid, and some of them perhaps acute tuberculosis, but chiefly typhoid. In fact, I think the addition of the two columns, the typhoid column and the remittent, intermittent, typho-malarial congestive and simple continued fevers, would give a truer typhoid death rate in the City of St. Louis than any other of the statistics that we could get.

"Q. Is it probable that any of the deaths reported from these causes during a series of years might, with modern methods of diagnosis, appear under some other heading?

"A. Yes, I think that the majority of those under the heading of remittent, intermittent, typho-malarial etc., if examined carefully by skilled clinicians, would be definitely diagnosed as specific diseases which we know about.

"Q. Are there any other reasons on the clinical side for confusion of diagnosis in dealing with these diseases?

"A. Yes, there are reasons, especially where men are not trained in the most modern methods of diagnoses, where it would be extremely difficult for a practitioner who has not been trained in the recognition of the malarial parasite, to decide between many cases of malaria and many cases of typhoid fever.

"It would be extremely difficult for a man who is not familiar with the modern agglutinative and bacteriologic tests to distinguish between many cases of typhoid fever and cases that are not typhoid, but resemble it.

"Q. What is the final and distinguishing differential test for typhoid fever and for malaria?

"A. The most important clinical test we have for typhoid fever, if I may say, a single test, the most important single test, though no one test is sufficient, in my opinion, to rely upon always in the diagnosis of typhoid, the most important single test is the Widal reaction or agglutinative test. More impor-

tant still is the symptom complex along with the presence of the Widal reaction. The whole condition of the patient, the temperature, epistaxis, the mental condition, the abdominal distension, the tenderness and gurgling in the abdomen, the character of the stools, the enlargement of the spleen, the rose spots on the abdomen, the character and time of disappearance of the headache, the onset of the delirium when it occurs, and so forth.

"Q. For malaria, what is the final distinguished differential test for that fever?

"A. For malaria, the one test, above all others, is the demonstration in the blood or tissues of the patient of the malarial parasite, by microscopic observation.

"Q. What is the cause of malarial fever?

"A. There are three great varieties in malarial fever, each due to a specific protozoan parasite, easily recognizable under the microscope; three varieties easily distinguishable from one another. The nature of the symptoms being easily predicable by one familiar with the life history of the parasite by simply an examination of the blood—microscopical examination of the blood.

"Q. Are these tests always applied by physicians?

"A. Unfortunately not, for only a comparatively small percentage of physicians are trained in the method of making the examination.

"Q. Are the symptoms of these diseases baffling, so that even an experienced physician might sometimes be deceived in his diagnosis unless modern tests were applied?

"A. Yes, sir; that is true. It is absolutely certain if these statistics are reliable, that there has been no increase.

"Q. What do the statistics show?

"A. The statistics show that the total number of deaths reported from typhoid and the remittent grouped together, run along at a tolerably constant figure. The figures, however, show in the typhoid fever column alone an increase in the number of typhoid cases; quite a marked increase during the last

three years, from 1900 to 1902. They also show quite a marked diminution in the remittent and intermittent group during the last three years. There has evidently been simply a transfer from the remittent column to the typhoid fever column. In other words, typhoid fever has been diagnosed more often during the last three years than it has in the last preceding years. There has been no greater number of cases, but the diagnosis appears to have been better. That the diagnosis is not yet good by many of the physicians in St. Louis is obvious from a large number of cases still reported in the remittent group.

"Q. Are you talking about cases or deaths?

"A. Deaths. When I say cases here I mean deaths every time. And I have no doubt that the discrepancy of cases existing would be infinitely greater than the death report shows.

"Q. Will you read into the record the statistics upon which you base that information, calling particular attention to the conditions before 1900 and since 1900?

"A. Well, whereas, with the exception of obvious epidemic years, the typhoid from 1890 to 1899—the death rate varies between 95 and say 215.

"Q. That is per 200,000?

"A. No, this is the total number of deaths in the years.

"Q. You say the epidemic years. What years do you have reference to?

"A. The year 1892 was obviously an epidemic year of typhoid fever, as there were 441 deaths reported from typhoid fever in St. Louis that year.

"Q. Excluding that year?

"A. Excluding that year, the death rate runs along and varies between 95 and 215, and there are two years with 106 and 107 deaths from typhoid.

"Now, in 1900 the deaths from typhoid are 168; 1901, 198; 1902, 222.

"And whereas, in the remittent group the lowest number of deaths before the year 1900 in that group, is 134, the highest number of deaths being in the epidemic typhoid year, 326, just

where we would expect it to be, but in 1900 these numbers drop away down to 112 for 1900, and to 80 for 1901, almost one-half what it was in any year preceding 1900, and in 1902 to 102. The total numbers, however, for the whole ten years run along in a fairly constant way. The total numbers for the two groups added together run along in a fairly constant way, indicating clearly to one who is familiar with the way these deaths are diagnosed, that there has been a transfer during the last three years from the remittent group to the typhoid group, a transfer which is most commendable, because it shows that a more accurate diagnosis has been made of typhoid fever during the last two or three years. I mean by that, the physicians have reported to the Health Department more cases of typhoid and fewer cases of remittent, but that there are still far too many cases being reported by the physicians of St. Louis as remittent, intermittent, typho-malarial, congestive fever, etc., is clearly shown by comparison with the Baltimore typhoid death rate. The conditions of the two cities are not dissimilar, and typhoid and malaria exist, in all probability, in about the same proportion in the two cities but whereas in Baltimore the typhoid fever is very much more abundant, as compared with the remittent group, the explanation, in my opinion, is that typhoid fever is better diagnosed in Baltimore than it is in St. Louis, and that is not surprising, because very important studies have been made during the last ten years in Baltimore on typhoid, and on malaria, perhaps the most important studies in the country, and the city is being repeatedly filled with young practitioners who have been trained under the men who have made these special investigations in typhoid and malaria and nearly all young men who go out into practice in Baltimore from the Johns Hopkins University have a skill in making the diagnoses between the two diseases, so that I feel sure that there is still a large number of cases in this city being put in the wrong list; that physicians are not yet diagnosing typhoid fever as they ought to do.

"Q. From your investigations and consideration of the

vital statistics of the City of St. Louis, has there been an increase, in your opinion, in the typhoid death rate since 1900 over the death rate that existed in St. Louis for the period of five years prior thereto?

"A. No, there has not been an increase.

"Q. Assume, professor, that in 1900, or the latter part of 1899, the Board of Health of the City of St. Louis sent out a specific circular to all the practitioners in the City of St. Louis, calling particular attention to the typhoid conditions existing here, and asking for a special report upon cases of typhoid fever; would that, in your opinion, have any influence—

"A. Yes, I think it would—I think it would, for this reason, that it is not an uncommon practice among physicians to designate cases that they regard as typhoid fever themselves as remittent or continued, or typho-malaria, or malarial fever, for the express reason of not exciting too much the fears of their patients. I know that that has been done by physicians. Patients are afraid of typhoid fever, and they naturally beg of their physicians to tell them what the disease is, and sometimes when one actually feels that the case is one of typhoid, he will say to the patient that it is remittent fever, or typho-malaria, or something of that sort, because he uses a clinical term which is true. Typhoid fever has a remittent chart sometimes.

"Q. Is there such a fever recognized by modern physicians equipped with modern researches, as typho-malarial fever?

"A. The best clinicians avoid the term altogether, for this reason that it is now possible to tell in every case, practically, whether we are dealing with real typhoid fever or real malarial fever, or, as ocasionally it has happened, a mixture of the two infections. There are a few cases in which the typhoid fever bacillus is invading the body at the same time that the protozoan malarial parasite is invading the body. If any case deserves to be called typho-malarial fever, it is such a case which is a mixed infection, but the term as used formerly, and as used generally, referring to the clinical course of the disease, a course that ran several weeks, like typhoid, but that had had marked

exacerbations and diminutions of temperature, and associated sometimes with chills, is improper.

"Q. How does the death rate from typhoid fever in the City of St. Louis, as you interpret the vital statistics, compare with the statistics of Baltimore and other cities?

"A. The death rate in St. Louis is not excessive, as compared with Baltimore and corresponding cities.

"Q. With what other cities have you compared them?

"A. I have compared them with figures from Philadelphia, Boston and New York; and especially as compared with Philadelphia the figures in St. Louis are very moderate." (See Vol. 8, pp. 7090 to 7099.)

Dr. Victor C. Vaughan testified as follows:

"Q. Have you made any special study upon typhoid fever or malarial fever from the standpoint of a bacteriologist and a clinician?

"A. I have.

"Q. In connection with such study as you have detailed have you taken up the question of the proper diagnosis of fevers, of the kind known as typhoid and malarial?

"A. I have.

"Q. How extensively, doctor?

"A. Our commission had charge of all the diagnoses that were made in the army camps after the appointment of the commission, that is, we selected the men and put them to work and overlooked their work in the various camps in the United States.

"Q. Have you had any experience in the diagnoses of these fevers, either in the laboratory or at the bedside?

"A. I have had experience both in the laboratory and at the bedside.

"Q. What is typhoid fever and its clinical diagnosis?

"A. Typhoid fever is an acute septicemia, due to infection with a specific germ known as bacillus typhosus.

"Q. What is malarial fever and its clinical diagnosis?

"A. Malarial fever is a disease due to infection with a

malarial parasite, of which there are at least three well known varieties.

"Q. What is intermittent, remittent, typho-malarial, congestive and simple continued fever and their clinical diagnosis?

"A. Most of the cases diagnosed under those different heads are forms of typhoid fever. Malaria is sometimes called remittent fever, but the majority of the cases in this country that are diagnosed under those heads, especially in the northern parts of the United States, are really cases of typhoid fever.

"Q. Are remittent, intermittent, typho-malaria, congestive and simple continued fevers distinct types of disease and so recognized by bacteriologists and clinicians?

"A. They are not.

"Q. What significance do you attach to those terms as applied to fever when they appear in vital statistics?

"A. They almost invariably—there are some exceptions, but almost invariably they mean typhoid fever.

"Q. Assuming that the number of deaths reported as occurring from typhoid fever in the City of St. Louis, as evidenced by the annual report of the Board of Health of the City of St. Louis, Health Department * * *. Assuming, further, that the number of deaths reported in the same reports under the heading remittent, intermittent, typho-malarial, congestive and simple continued fevers is as follows: * * * do the number of deaths reported as occurring from the typhoid fever alone in the City of St. Louis properly represent, in your opinion, the total number of typhoid deaths actually occurring in the city for the period in question?

"A. They do not.

"Q. What reasons have you for stating that they do not?

"A. My experience shows me that malaria is not a common disease in Missouri or in that section of the country. The disease itself is rare and death from the disease is exceedingly rare, so rare that, practically, it does not occur. You may ask me what I base that statement on. Missouri sent six regiments to the war in 1898. I have studied the records of all

these regiments, and, although in some of them many cases were diagnosed by the surgeon as malaria, more careful examination was instituted by our board, showing that these were not malarial cases, but they were cases of typhoid fever. One of these regiments remained, if I remember correctly—I can tell positively by looking at the records in Jefferson Barracks, practically a part of St. Louis, until July, 1898. While malaria was frequently reported by the medical officers in charge of these regiments, more careful examination showed that they were cases of typhoid fever. For instance, the Sixth Missouri developed 286 cases of typhoid fever and had 19 deaths from typhoid fever. The Sixth Missouri was stationed at Jefferson Barracks until early in August. I have not the exact date. It then went to Jacksonville, Florida, and there our board inspected the Sixth Missouri and studied the cases clinically and bacteriologically. They were cases of typhoid fever, and not cases of malaria.

"Q. How many cases of malaria were recorded?

"A. I cannot tell you exactly now.

"Q. That turned out to be typhoid?

"A. I cannot tell you from that regiment, but I can tell you from some other regiment.

"Q. I wish you would.

"A. Well, of 83 cases of so-called malaria from the Fifth Maryland that were sent to the hospitals in Baltimore, 80 cases proved to be typhoid fever. I think that is just about right. It was about that per cent. I have not the figures exactly here. That is substantially correct.

"Q. To what do you attribute the failure of these statistics assumed in the foregoing hypothetical question to properly disclose the number of typhoid fever deaths occurring in the City of St. Louis?

"A. For the reason just given, that malaria is certainly a very rare disease in Missouri, and death from malaria is much rarer, in this section of the United States.

"Q. You are acquainted with the conditions in St. Louis, are you not?

"A. Very slightly. I cannot say that I know very much about the local conditions existing in the City of St. Louis.

"Q. In the State of Missouri?

"A. Somewhat. I was born and reared in Missouri. I know something about it. I go back there nearly every year. I know something about the conditions existing in Missouri.

"Q. Why is it that the doctors employ the terms remittent, intermittent, typho-malaria, congestive and simple continued fevers to fevers that are recognized as being either typhoid or malaria?

"A. There are many reasons why doctors do this. In the first place, typhoid fever in its earliest stages is often a remittent disease, that is, it is a disease where fever exists for a few hours and then there is no fever. In its earliest stages it is a remittent disease. That is one reason why it is done. The second reason why it is done is that doctors really think they are dealing with malaria when they have typhoid fever, and I have no doubt the third reason that actuates doctors in using these terms is that they are less likely to frighten the patient and friends of the patient. It does not seem quite so dreadful a thing to have malarial fever as to have typhoid fever, and the fourth reason is that the means of accurately distinguishing between malarial and typhoid fever have been discovered only within recent years, and even now are not always in the hands of practicing physicians. These, I think, in sum and substance, are the reasons why doctors so frequently use these terms remittent, intermittent, typho-malarial, congestive and simple continued fevers, when actually they have typhoid fever to deal with.

"Q. Do you know of any city in the country where the death rate from malarial fever alone is as high as in the City of St. Louis, as evidenced by the number of deaths as assumed in the hypothetical question under the heading intermittent, remittent, typho-malarial, congestive and simple continued fevers, occurring in the health reports of the Board of Health of the City of St. Louis?

"A. I am sure there is no city in the United States where there are so many deaths from malaria fever as there reported. Of course, there may be cities where the deaths reported are equal to those in St. Louis, but there are no cities where there are that many malarial deaths.

"Q. *What proportionate deaths in the column under the heading remittent, intermittent, typho-malaria, congestive and simple continued fevers assumed in the foregoing hypothetical question as occurring in the City of St. Louis, as evidenced by the report of the Board of Health, in your opinion, should be classed as typhoid?*

"A. *I think 100 per cent. of them should be so reported. Now, of course, there may be a few of them that were not typhoid fever; they may have been something else.*

"Q. *What proportion as malarial fever?*

"A. *None.*

"Q. What do the mortality statistics of malaria show in cities where careful attention has been paid to malarial fevers, in regard to the number of deaths occurring from malarial fever?

"A. Well, there are practically no deaths from malaria in this country, unless it is in New Orleans or some other extremely Southern city. Of course, there may be two or three in a year in a large city. In Albany five cases were reported in the last year from malaria, but it is very doubtful that those were really malaria.

"Q. Is it generally recognized by bacteriologists and physicians that classifying typhoid fever in one column and intermittent, remittent, typho-malarial, congestive and simple continued fevers in another column in board of health reports of cities is an improper classification from a scientific standpoint, as affording a true indication of the mortality from typhoid fever and malaria?

"A. It certainly is.

"Q. Assuming that the reports of the Board of Health of the City of St. Louis by the month from 1895 to 1903, inclusive,

under the heading typhoid fever, which, for the purpose of convenience, is designated 'A' in the table that follows and as remittent, intermittent, typho-malaria, congestive and simple continued fevers, for the sake of convenience designated as 'B' in the table, as follows, which table was prepared and sworn to by Professor Jordan * * * will you please state what construction you place upon this table as showing the relative mortality from typhoid fever and malarial fever in the City of St. Louis during the period covered by the foregoing table?

"A. I think the total deaths there, as reported from all of these cases more accurately give the number of deaths from typhoid fever.

"Q. From a careful consideration of the tables which have just been assumed in the hypothetical question, what conclusion would you draw as to whether the outbreaks of typhoid fever in St. Louis were of an epidemic during this period or the normal death rate due to local causes or otherwise?

"A. Well, without knowing anything about the local conditions in St. Louis, simply as a student of epidemiology, and looking at the distribution of these diseases according to months, I should say that the probabilities are that typhoid fever in St. Louis, with the possible exception of the year 1892, was due to local causes rather than to any infection of the general water supply. When there is an infection of the general water supply, as a rule the outbreak of typhoid fever is explosive in character, that is, there are a great number of cases which occur within a short time. They are not distributed along so evenly through the month. That is the rule. Of course, there may be possible exceptions as to this. I do not know about the local conditions, but when there are positive infections (certain infections of the water supply) the outbreak of typhoid fever is of an explosive character, as happened at Grand Forks, North Dakota, some years ago; Duluth, Minnesota; at Butler, Pennsylvania, recently; Plymouth, Pennsylvania, some years ago; Ithaca, New York, recently, and as now occurring at Water-

town, New York. That is the general rule of epidemics due to the infection of the water supply.

"Q. Assuming that on April 1, 1895, the total number of wells in the City of St. Louis was 4,846, and assuming that in pursuance to an order of the Board of Health of the City of St. Louis, directing an examination of these wells, that the City Chemist, after an examination of 59 of these wells, condemned them as being unsanitary; and assuming, further, that in August, 1895, upon a report of the City Chemist condemning seven more of the wells, the Board of Health of the City of St. Louis passed a resolution to the effect that the City Chemist should make no further examination of the wells in question, and that since 1895 none of these wells have been condemned; what effect would the presence of such wells of known pollution have in affecting the typhoid condition in a city such as St. Louis?

"A. As I stated a moment ago, these figures as given here showing the distribution of typhoid fever render it highly probable that the local conditions, such as infected or polluted wells, indicated the distribution of typhoid fever by contact were the causes of the spread of typhoid fever in St. Louis rather than the infection of the general water supply. I should answer your question, then, specifically by saying polluted wells, if they were specifically polluted with typhoid fever, the use of the water from such wells would undoubtedly cause typhoid fever * * *.

"If you take the years from 1890 to '99, inclusive, you have total deaths of 3,708 for ten years. That would give an average death rate of 370. If you take the four years since 1899, it will give you 1,261 deaths, or an average of 315 deaths, so there would be, if you included all the years from 1892 to 1903, inclusive, then the average would be greater before 1900 than since 1900. If you cut out the years 1892 and 1893, it would be smaller.

"Q. Assume that two circular letters, one issued in the fall of 1900 and another issued in the fall of 1901, were issued by the Health Commissioner of St. Louis, calling the attention

of physicians to the fact that the law required them to report all cases of typhoid fever and all deaths of typhoid, and at that time that letter was sent out, the question of opening the Drainage Canal was being agitated in the public press of St. Louis, and there was considerable discussion and an investigation was going on at that time of the analysis of the samples of water collected, etc., and was attracting considerable attention. From your examination of the statistics of St. Louis, as heretofore assumed in the hypothetical questions heretofore asked you for the year 1900, 1901, 1902, as compared with previous years, does the effect of such a letter, assuming that the same has been sent out to the doctors by the Health Department of St. Louis, manifest itself in those statistics?

"A. It probably does. I should assume that the object in sending out such a letter was to get a more perfect report of deaths from typhoid fever, and I should judge from the decrease you see here in the deaths from malaria that such object was accomplished.

"Q. In what way does the effect of such a letter appear from the statistics?

"A. By an increase in the number of deaths reported from typhoid fever.

"Q. Is there any proportionate loss from the typhoid malarial column manifested in the statistics?

"A. I believe there is; yes, sir. While in 1901 there were only 80 cases, the smallest number in any one year, from and including 1900. In fact, all three years, 1901, 1902 and 1903, the number of deaths reported as being due to malaria is less than any year preceding that.

"Q. From your examination of the typhoid and typho-malarial deaths as assumed in the foregoing hypothetical question, what is your opinion as to whether these two tables, taken separately, correctly show the typhoid conditions of the City of St. Louis for the period mentioned?

"A. The two tables, taken separately, do not correctly show the death rate.

"Q. Upon what do you base your opinion that they do not correctly show the typhoid condition in St. Louis, taken separately?

"A. My opinion is based upon the fact, which is well known to most physicians, and certainly I have special reasons for knowing it, that malaria is not a frequent disease in this country and is certainly a very rare cause of death.

"Q. From your knowledge of these classes of fevers mentioned in the two columns of vital statistics as heretofore assumed, how should they be treated by a bacteriologist, statistician and clinician in order to arrive at the typhoid fever mortality in the City of St. Louis?

"A. They should be combined, that is, the two tables should.

"Q. Have you made any study of comparisons between the typhoid and typho-malarial groups of the City of St. Louis with those of any other city?

"A. I have made some studies of the comparison between typhoid fever in St. Louis and typhoid fever in other cities. I have here the number of cases reported and the number of deaths in each year from 1896 to 1902, inclusive, for New York City, Minneapolis, Philadelphia, Richmond, Buffalo, Albany and Cleveland, and it is rather interesting to note that the death rate in Buffalo has increased quite markedly since 1899.

"Q. That is the year of the opening of the canal, is it not?

"A. I believe so. Shall I give you the figures?

"Q. I wish you would?

"A. In 1896 there were 274 cases in Buffalo, reported, with 68 deaths.

"In 1897, 2201 cases reported, 63 deaths.

"In 1898, 280 cases reported, 98 deaths.

"In 1899, 212 cases reported, 88 deaths.

"In 1900, 322 cases reported, 90 deaths.

"In 1901, 405 cases reported, 98 deaths.

"In 1902, 385 cases reported, 125 deaths.

"Of course, in New York there has been a big increase in

typhoid fever. I imagine, however, that is due to the enlarging of the city rather than to any other cause, but the cases there jump from 1,950 in 1899 to 2,658 in 1900, and in 1902 getting up to 3,871.

"In Minneapolis there has been an increase, if we exclude the year 1897, when there was an epidemic of typhoid fever in Minneapolis.

"Q. What has been the general tendency in regard to typhoid fever during the last five years?

"A. Do you mean so far as its location is concerned?

"Q. As to increase or decrease?

"A. I have an idea, and I think most epidemiologists have an idea, that typhoid fever has been more widely disseminated over the country and there are more cases and more deaths from typhoid fever. I do not mean that the per cent. of deaths has increased, but the number of cases has increased, and, consequently, the number of deaths has increased, and I dare say that this is in part due to the distribution of typhoid fever from the camps in 1898. That is probable.

"Q. Does St. Louis occupy a different position in regard to this increase, in your opinion, than the other cities you have referred to?

"A. No, there are other cities which show some increase. Of course, I might have picked out cities that showed marked increase, but these are cities which I had already looked up in making my government report, and I simply took them as I had them.

"Q. Is there such an increase, as you observed, as would be characterized as an epidemic?

"A. No. An epidemic of typhoid fever, and especially a water epidemic of typhoid fever, is where the increase in typhoid fever amounts up to 100 per cent. or more, and even 200, 300 or 400 per cent.

"Q. What is the character and nature of the increase that you observed from a study of these statistics?

"A. On the whole, a gradual increase, such as you might

expect would be due to local conditions, especially if wells were getting more and more filthy and were not condemned." (7315 to 7328.)

Professor George Dock, of Ann Arbor, whose testimony in this case, based upon valuable personal experience, sheds a great deal of light upon the subject under discussion, testified in part as follows:

"In Galveston I found they were diagnosing practically no typhoid fever at all. I saw lots of typhoid fever patients there. I was able to see that cases that were diagnosed as malaria and typho-malaria were typhoid fever, and my experience showed me that none of these cases had malaria. I did, however, see fatal cases of malaria. They were all cases that came from the tropics, Nicaragua or Panama, or else cases from the interior of Texas, where they occasionally have very severe forms of malaria.

"I became very much interested in the practical diagnosis of so-called malarial diseases, continued malaria and various local names that are given to this disease.

"On one occasion I made an offer to visit any patient having typho-malaria or continued malaria, and examine the blood free, in order to settle whether it was malarial fever or could be diagnosed as typhoid. I never had occasion to have my offer accepted. I saw many cases and examined them all very thoroughly; read several papers on that subject and have been quite widely quoted, and became looked upon as somewhat of an expert in malarial diseases.

"From Galveston I went to Ann Arbor, and there I had the same experience I had in the South. I found that the doctors were diagnosing many cases of typho-malarial fever. I examined many of those cases post-mortem as well as in life, and I was able to show the same thing, that cases that were diagnosed as typho-malaria and continued malaria were all cases of typhoid fever. In Michigan I did not see any fatal cases of malaria at all. I have cases sent in under the diagnosis of typho-malaria, or some similar name, and I have frequent occasion to clear up the diagnosis.

"The Mississippi Valley is, of course, a great point in both of these diseases, and in studying the features of typhoid and malaria, I studied the conditions and talked with many doctors throughout there, and when I lived in Galveston I always went through St. Louis two or three times a year, and usually stayed there a day, and had opportunity for looking around the town from a malarial standpoint; that is, with the eye of a malaria searcher. I was looking for malaria everywhere. I have given attention to malaria in St. Louis. I examined the outskirts of the city and formed the opinion that I have, which was not based upon examinations of my own patients, but I had some correspondence with doctors in St. Louis, because I was writing on malaria, and the doctors there wrote me as to their methods of examination and various questions connected with malaria, and I gathered some information that enabled me to form an idea on evidence that we could not see with our own eyes.

"I have read the literature on the subject and have read a number of articles in the medical journals. I might mention an article by Dr. Bremer, a well known physician of St. Louis, and I have the article with me in a medical journal known as the Medical Review, published in St. Louis, and the number I think is the number of August, 1905. Dr. Bremer states: 'In our part of the country, and probably throughout the larger part of the United States, physicians are apt even today to look upon many ailments as due to malaria which in reality have nothing to do with this disease, either directly or indirectly.' There is a footnote to this, as follows: 'This means St. Louis and environments in particular, and the Mississippi valley in general, but it probably applies to the whole United States.'

"In another place he states as follows: 'Periodic chills followed by high temperature which mark the initial stage of so many cases are generally interpreted as due to malaria, hence the erroneous and mischievous diagnosis malaria, remittent fever or typho-malaria, under which name so many cases of typhoid figure in the reports of our City Boards of Health.'

"Also the following: 'Now a practical question, to what extent does malaria exist in our part of the country (the Mississippi valley), basing my opinion on the examination of about five hundred individual cases of all sorts of individuals. I have come to the conclusion that in our city at least malaria is an extremely rare disease; so rare indeed is this disease, at least in its pronounced forms, that when about four years ago I went to the city hospital for a number of months in the hope of finding a good plasmodium infected subject my efforts were unsuccessful for a long time. The cases pointed out to me by attending physicians as malaria and treated as such proved to be infections which had nothing in common with that disease.'

"I may say that this bears out the experience I have had myself in various places having the general climatic conditions of St. Louis in mind, and especially with the experience I had in 1898 in some of the army camps.

"I was asked by Surgeon-General Sternberg of the United States army at that time to visit certain army camps in order to examine the blood of the patients diagnosed largely as malaria. In accordance with that I examined the Sternberg General Hospital at Chickamauga, the hospital at Knoxville and at Camp Meade, Pennsylvania. At that time most of the cases of typhoid in the army camps were diagnosed malaria. In the Sternberg hospital, for example, there were four hundred patients when I got there, and practically all of them had a diagnosis of malaria in one form or another, typho-malaria, bilious remittent, or some such name. I examined most of these patients individually. I examined their blood and examined their clinical features, with the result that I found only one out of the whole four hundred had malaria fever.

"I also made some autopsies on patients dying with so-called malaria fever, and found that they had typhoid fever without malarial.

"Then I went to Camp Meade, where the conditions were practically the same. Eighty per cent. of all the fever cases had a diagnosis at their bedside of malarial fever with various

modifications. In a few days those diagnoses were changed just around, 80 per cent. typhoid and 20 per cent. malaria. I examined all the suspected cases and found only one patient out of the several that really had malaria. The disease was in practically all the cases typhoid. At Knoxville I was not able to find any malarial cases. I reported this matter to the Surgeon-General, but my report has not yet been made public.

"I have made a special study of typhoid fever for about twenty years; have made several hundred autopsies on patients who died of typhoid fever, not all of them my own patients, however, and on a great many patients diagnosed as either having typhoid fever or having some other disease. In such cases the diagnoses were often wrong. From such experience I have seen a good deal of typhoid fever. I have made a special study of the so-called germ disease, and they came intimately within the scope of my experience. I have studied typhoid fever and malaria fever from the standpoint of a bacteriologist and clinician.

"Typhoid fever defined with its clinical diagnosis, intermittent, remittent, typho-malaria (the word typho-malaria is also used as a cover for diagnostic difficulties), congestive fever, simple continued fever.

"Remittent, intermittent, typho-malaria, congestive and simple continued fevers are not distinct types of disease, and so recognized by bacteriologists and clinicians. Usually all such names are included by careful boards of health under the heading of typhoid fever, and, as I have just said, they usually refer to typhoid fever. My own experience with them among doctors and in the hospitals and in the post-mortem room is that they are applied to typhoid fever in a majority of cases. An examination of the blood of malarial on one hand, or the typhoid reaction on the other, usually clears them up very quickly.

"Assuming the number of deaths reported under the head of typhoid fever in St. Louis in the Board of Health statistics, as contained in the hypothetical question, the figures show an increase during the last ten years, but not a great increase; the

increase for the last five or even six years, from 1895 to 1903, is a steady and gradual increase. There is no one point there where one can see a certain increase out of proportion to the general line.

"I am particularly struck by this increase since 1898, because in 1898 the doctors all over the country had their attention very strongly called to the wrong diagnoses that were formerly made of the so-called typhoid diseases, and the attention of the public has been very strongly called to it. As shown in the army camps especially, that soldiers were dying of typhoid that were supposed to have malaria. The people found out it was possible to make a more correct diagnosis, and doctors, in my experience in various parts of the country, have been more careful in their diagnoses since 1898, and while it was an increase, I would not call it a great or a sudden increase.

"The number of deaths reported as occurring from typhoid fever alone in the City of St. Louis does not, in my opinion, properly represent the total number of deaths actually occurring in that city from typhoid fever. The most important reason is that the death rate from malarial diseases is altogether too high, too high for every year. Take an exceptional year for typhoid when there was an accidental condition; the malaria was 50 per cent. higher than it was two years before. In 1890 there were 226 cases of the malarial disease.

"I include all these various diseases in malaria; in 1892 there were 326 cases. Now, from studying malaria very carefully at that time, I say there was no reason why malaria should increase in a city like St. Louis to that extent at that time. The death rate every year is altogether too high, and is higher than I believe possible.

"Malarial fever described, with the different types of malaria.

"The intermittent form of malaria is common in the central states of the Mississippi valley, and that form of malaria is never fatal; nobody ever dies of it unless he has had some previously existing fevers. The reason why doctors employ

these terms are various. In the first place, very often the doctor has an incomplete idea of the diagnosis of typhoid fever; that is, his idea of typhoid fever is not correct. He does not use the proper method of diagnosis. Very often it is done for what might be termed business or social reasons. The doctor does not like to give out the impression that his town has a lot of typhoid fever in it, and may often have an intimation from the health authorities not to give it out. In the army camps surgeons were frequently ordered by superior officers not to make out a diagnosis of typhoid fever. The diagnosis of typhoid fever is always very unpopular. They fall back on some other word, especially typho-malaria. Cities that are going to have World's Fairs in them always object to having such a name used.

"From the statistics that I have been furnished, and from my experience in the diagnosis of typhoid fever and typho-malaria fever, I should say it would be impossible to say exactly how many cases in the typho-malarial list should be classified as typhoid fever, but anywhere between 50 and 90 per cent. of the so-called ought to be typhoid; at least 50, and probably as many as 90. For a city like St. Louis a death rate of two or three per cent. from malaria fever would be very high. No cities in this country have actual statistics on malaria. The best places to get statistics are in hospitals where they pay special attention to malaria, and the experience in a hospital like the Johns Hopkins Hospital, where they have climatic conditions rather more favorable for malaria than those of St. Louis, might be taken. In ten years they were able to get only three deaths from malaria fever; that is practically nothing at all in comparison to what St. Louis has in one year. It is generally recognized and most careful boards of health refuse to accept such classification because all such diseases should be put in the typhoid table. The Board of Health of Michigan, for instance, orders that all typho-malaria be classified under typhoid, and the new classification recommended by the United States Census makes the same recommendation.

"After considering the typhoid death rate, and the typho-malarial death rate by the month for the City of St. Louis from 1895 to 1903, the chief conclusion I draw is, to conform to what I said before as to statistics regarding malarial diseases, that they are not altogether faulty. It comes out more clearly when we study the reports of malarial diseases by months, where the death rate is altogether impossible for malaria in the latitude of St. Louis. For example, the typhoid deaths reported for the months including January, February, March and April, nobody dies of malarial fever in those months. Further, malarial fever cannot occur then, even in such a malarial country as the Philippines malaria does not kill all the year around. In several months corresponding to our winter season they do not have any deaths from malarial fever. A study of this table would be enough to show that the whole malarial statistics of that town are seriously faulty.

"The added totals of typhoid fever and typho-malaria do not indicate a marked increase in typhoid fever; however, they indicate a slight and gradual increase from the year 1898, an increase that I would explain partly from the fact that the diagnosis of typhoid fever has become broader, all over the country more cases are being included. There is a tendency everywhere to increase the proportion of typhoid cases in that way. There has been a slight and gradual increase. By combining the two groups the increase is not as great as the increase under typhoid fever deaths reported in the Board of Health reports. There is nothing in the statistics to show that an explosion of typhoid fever occurs. The increase, for example, is slightly more marked for the year 1901, but even there it is not at all striking; it is not such a thing as we find, for example, in the case of Butler, Pennsylvania, or in the case of Cornell College, in the Town of Ithaca.

"In regard to the circular letter sent out by the Board of Health of St. Louis, I think the sending out of such a letter would explain the rise as it occurred in the last five years. Of course we have to stick to the last two years on account of the

letter, but the increase is not so great as one might expect. Such an order calling attention of physicians to the law requiring them to report all cases of typhoid has been carried out in other cities, and the increase has always been marked; I mean has been distinct. Here there is an increase too, but it does not strike me as being very much greater than it was in the three years before.

"The typho-malarial fever goes down as one might expect. Doctors having their attention called by the notification would report more cases as typhoid and less as typho-malaria than they would before.

"My opinion is that the two tables, taken separately, do not correctly show the typhoid condition, for the reason, I think, I have mentioned before. The safest way would be to look upon all those anomalous fevers as typhoid.

"Assuming the combination of the two tables and the population of St. Louis according to the United States census reports, and the intervening years estimated by Farr's formula, the table does not show that there has been a marked increase. On the contrary, a slight increase, such an increase as I would ascribe rather to increased care in diagnosis rather than to any outside condition.

"The figures are compatible with such slight increase as we find here, and typhoid fever in most places, like most other diseases, runs cyclically, without any fresh conditions from the outside, or any marked condition in the matter of water supply or drainage. I should think there would have been conditions at St. Louis which would have increased the typhoid incidents. The fact that many people were going there, people not accustomed to the climate, perhaps living carelessly. In nearly all such times we see such epidemics break out.

"One of the most serious sources of typhoid fever, where they have surface drainage and wells both, the conditions are especially dangerous. In cities that have a good water supply, and still have wells, they always have a distinct amount of typhoid fever. The wells in small cities and in rural districts

are very serious causes of typhoid fever. The number of wells in St. Louis would be a very serious source of typhoid fever.

"From a consideration of the statistics and the typhoid condition in the City of St. Louis, my opinion is that the increase indicates a change in the conditions of the City of St. Louis itself rather than in the main water supply. Supposing that the main water supply comes from a river; a change in the condition of the river water is always indicated in such cases by a marked increase. As to such an increase as we have here it is altogether compatible with changing local conditions, such as wells and the ordinary course of typhoid epidemics."

Cross-Examination.

"Dr. Blickhahn of St. Louis wrote me after he had been working on malarial fever for two years that he had never been able to see a certain form of malarial organism called the crescent. I was rather surprised at that, because I would have rather supposed that he would find crescents in St. Louis. Crescents are found in more severe forms of malaria fever. Dr Blickhahn wrote me he had not been able to find any, and asked me to send him one of my specimens. I sent him some specimens that I had brought from Texas. I supposed he had simply overlooked them, but he wrote back and said he had really not seen them up to that time. That was additional evidence that severe forms did not occur frequently there, although, of course, they might occur now and then. That was in 1903 and 1904.

"Q. What fevers known as fevers which would produce death may in a sense be associated with typhoid fevers?

"A. In this country there are practically none, especially in the northern latitudes.

"Q. From your examination of the malarial records of St. Louis you have arrived at the conclusion that physicians of that city are not competent to make determinations as to the character of the disease?

"A. I would not say that all the physicians, but I have

already put myself on record as saying that a large number of the physicians are not making a correct diagnosis of this disease, and I have no hesitation in repeating it here.

"Q. And you have expressed that opinion altogether from the record?

"A. Partly from the record and partly from the facts bearing upon the occurrence of this disease, and partly from my experience in certain definite places where I have investigated the actual cases, and partly by becoming familiar with a good many doctors from all over the country. In the army camps, for example, I saw doctors from every state, and saw how they made their diagnosis, and I was able to see that a large majority of them were making faulty ones, and I was able to demonstrate that they were."

(See Dock's testimony, Vol. 8, pp. 7045 to 7071.)

Professor William S. Thayer, for nearly fifteen years in charge of the Johns Hopkins Hospital at Baltimore, and Professor of Medicine in the Johns Hopkins University, testified in this case upon the subject under discussion, and his testimony demonstrates certain phases of this inquiry, which defendants deem of great importance to be considered in connection with the proposition here sought to be established. His testimony upon this point is set out as follows:

"Q. Have you made a special study of the so-called germ diseases?

"A. Yes, sir, I have, in regard particularly to malarial fever and typhoid fever, and in a general way to those infectious diseases which come into the practice of a practitioner of general medicine; I have made a special study of malarial fever and a number of phases of typhoid fever.

"Q. Do the diseases caused by germs come within the scope of your study?

"A. They do. At least I may perhaps say, most of them.

"Q. Which diseases have you made a special study of, that is germ diseases?

"A. Malarial fever and typhoid fever particularly.

"Q. Have you made any study upon typhoid fever and malarial fever from the standpoint of a bacteriologist or clinician?

"A. I have been studying them clinically, steadily, since the beginning of my practice, and I have made special investigations with regard to the parasites of malarial fever.

"Q. In connection with such study as you have detailed, have you taken up the question of the proper diagnosis of fevers of the kinds known as typhoid and malarial?

"A. Yes, I have.

"Q. Have you had any experience in the diagnosis of these fevers, either in the laboratory or at the bedside?

"A. I have had continued experience, both at the bedside —more particularly at the bedside—and also in the laboratory for the last—since 1889—since the summer of 1888 really.

"Q. What is the meaning of clinical diagnosis?

"A. Clinical diagnosis is bedside diagnosis—at the bedside of the patient. It is bedside diagnosis in contradistinction to pathological or post-mortem diagnosis.

"Q. What is typhoid fever and its clinical diagnosis?

"A. Typhoid fever is a disease due to the entrance into the organization of a specific bacterium, the typhoid bacillus. That organism enters into the body in all probability in the vast majority of cases through the gastrointestinal tract, passes into the general circulation, and causes a septicaemia; in other words, a general blood poisoning. It furthermore is associated with certain anatomical changes, more particularly a swelling of Peyers' patches and the solitary follicles of the small intestines, enlargement of the retroperitoneal glands, and an enlargement of the spleen, together with certain widespread degenerative changes in various organs throughout the body. This results in a clinical picture, the more important features of which are due—not to the local changes, but to a poisoning produced by certain products of the growth of this bacillus. Those symptoms are in the first place a fever of usually rather gradual onset, preceded often by a week or ten days or so of sensations

of malaise and headache, not infrequently nose bleed, a gradually rising fever which reaches its height at the end of from several days to a week as a rule and lasts on an average of about three weeks, falling gradually to normal. It may last a short time and it may last a very much longer time. This fever is associated usually with certain other symptoms which are of considerable importance, a generally dull, apathetic condition of the patient, which is spoken of as the typhoid condition, and which, though it may be present in other intoxications, is rather particularly characteristic of this disease. The appearance of the eruption, which is present in a majority of cases, though not always; this appears usually about the end of the first or beginning of the second week, an eruption of small so-called 'rose spots.' Very often there is a slight bronchitis. A palpably enlarged spleen. There are not infrequently associated with these symptoms others which are due more particularly to the local lesions, such, for instance, as diarrhoea, the result in most cases of severe intestinal involvement, abdominal distention, or of other complications such as hemorrhage of the bowels due to ulceration through a large vessel, or perforation of the intestines, which occurs in a small proportion of cases. Towards the end of the first week, or by the tenth day, as a rule there appears in the blood serum, a substance which, when the serum is added to cultures of the typhoid bacillus, even though the serum be diluted to a high degree, produces a clumping and loss of motility of the bacilli—the phenomenon known as the Widal reaction. This reaction when positive, after proper precautions have been taken in the procedure, is specific of typhoid fever.

"It is fair to say that it sometimes does not appear until very late, and it is not impossible that there may be cases of typhoid fever, though very rarely, in which it does not appear, but this is probably of the utmost rarity.

"With regard to the diagnosis of typhoid fever I might say one word more. In contradistinction to what is true in fevers due to or associated with local inflammatory processes, the white

corpuscles of the blood are diminished in number in typhoid fever, while in all diseases due to local inflammatory process they are increased—sometimes an important diagnostic point.

"But the diagnosis of typhoid fever depends upon a careful consideration of the whole situation.

"It is often impossible to make a positive diagnosis of typhoid fever before the end of the first week, but it is rarely the case that one is not able to recognize typhoid fever if the disease is carefully observed.

"Q. Are all the symptoms which you have indicated in your answer always present in a case of typhoid fever?

"A. No, there is not a single one of the symptoms of typhoid fever which might not be absent from a given case. While one can draw a good average picture, such as one reads in a text book of medicine, the individual who learns to recognize typhoid only from such a picture is bound to make many mistakes. The diagnosis can only be made by a careful consideration of all the different symptoms, putting them together and drawing proper conclusions, and in cases which are not typical proper diagnosis demands experience. There is no disease in which experience is more important than in typhoid fever.

"Q. What experience have you had and what studies have you pursued with malarial fever?

"A. Shortly after coming to Baltimore, in 1890—the fall of 1890—I began to devote myself especially to the study of malarial fevers as here observed. After five years' study Dr. Hewetson and I published a report on the subject in the Johns Hopkins Hospital reports, in which we gave the results of our studies of the malarial fevers and the malarial parasites. I continued my work afterwards, working principally on malaria up to 1900, and during that time published a number of papers. I published a text book, 'Lectures on the Malarial Fevers,' in 1897; in the spring of 1900 I delivered an address before the Congress of American Physicians and Surgeons on the recent progress in our knowledge concerning malarial fevers. I have also, I may say, looked into the matter personally in other parts

of this country, having made trips to Memphis, to New Orleans, to certain parts of eastern North Carolina and Virginia to look up special points.

"Q. What is malarial fever and its clinical diagnosis?

"A. Malarial fever, or more properly the malarial fevers, for there are several distinct types, are due to the entrance into the blood of specific micro-organisms. These belong to the lowest order of animal parasites. They enter into the red blood corpuscles of the infected individual and pursue their cycle of existence in the red corpuscles, producing characteristic symptoms in the patient. Here, as all over the world, there are three types of malaria. Tertian fever, Quartan fever and what is called Aestivo-Autumnal or tropical fever. The regular intermittent Tertian and Quartan fevers are characterized by chills or febrile paroxysms occurring at regular intervals. In infections with the Tertian parasites they occur every other day, in infections with the Quartan parasites every fourth day. Each paroxysm is associated with the ripening of a group of parasites. The parasites in these regularly intermittent malarial fevers exist in the blood in great groups. All the members of each group pursuing their development in unison and reaching their maturity at practically the same time. When a group of parasites reaches maturity each parasite breaks up into a larger number of fresh young organisms, which attack new corpuscles and begin again their development. The febrile paroxysms correspond to the period during which the full grown parasites are breaking up into the new brood. In Tertian fever this period occurs every other day. In Quartan every fourth day. In either instance, if multiple groups of parasites be present—groups which reach maturity on successive days—the chills will occur at more frequent intervals.

In infections with the third form of malarial parasite—the Aestivo-Autumnal parasites, the symptoms are somewhat different. These parasites are not as a rule arranged so regularly in groups. The stage of maturity with the liberation of the new group of parasites does not occur at such regular intervals.

Small groups of parasites may be segmenting almost continually. As a result of this one sometimes sees continued fevers or fevers with irregular intermissions or remissions. The malaria fevers are recognizable and diagnosticable by the examination of the blood under the microscope and the demonstration of the parasites, and need never be confounded with typhoid fever. They are also recognizable by the fact that they are curable by quinine. The only patients with malarial fever properly treated who ever die are certain cases of extremely pernicious Aestivo-Autumnal malarial cases, which die within forty-eight hours perhaps of the beginning of the treatment. No case of continued malaria which could be confounded with typhoid fever need ever be fatal. They always clear up under treatment with quinine, and no case of continued fever which lasts more than—well, to be most generous, four or five days after treatment with quinine, is malaria. That is a statement which in my experience can be positively made.

"Q. What are the known means of conveying the parasites of malaria whereby the disease is contracted?

"A. The only known way by which malaria can be carried is by the bite of a mosquito. The malarial parasites of all three varieties possess two cycles, one of which they pass in the stomach wall, and in the salivary glands in certain types of the mosquito-members of the genus anopheles. The other cycle they undergo in the human being. So far as known, and so far as believed by all who have particularly devoted themselves to the subject of malarial parasites, they do not exist outside of the human being or the mosquito. If a mosquito of the genus anopheles, at a fitting time of the year when the temperature is warm enough, bites a patient whose blood contains certain forms of malarial parasites, at the end of seven or eight days that mosquito will be capable of transferring the infection by bite to another human being. After careful investigation during the last six years—since this discovery has been made—there has not been revealed a single instance where malaria has originated except in the presence of this type of mos-

quito. And furthermore, most interesting experiments have shown that even in the most malarious districts the disease may be kept away by thoroughly protecting individuals from the bites of mosquitoes. And, on the other hand, it has been shown that by taking a given population and treating them with quinine in such a way that human beings are never allowed to have parasites in their blood, so that the mosquitoes can get them, the disease may be wiped out. Koch has done that in several places, and most striking were his experiments in a town of 700 inhabitants in New Guinea or West Africa. He went there before the beginning of the malarial season and put every one who had parasites in the blood under treatment. Paid no attention to the mosquitoes, but watched the people, and as a result there was no epidemic. So far as known the parasite does not live in the mosquito for more than several weeks or a month.

"Q. Have you ever found the parasite of malaria in the mosquito?

"A. Yes, I have. I have fed mosquitoes on patients whose blood contained malarial parasites and demonstrated intermediate stages in the mosquitoes' stomach.

"Q. Do you know of any recorded instance where the mosquito has been employed in transmitting malarial fever from one country to another?

"A. Yes, that was done in the case of Dr. Manson, the son of Dr. Patrick Manson, in London. The Italians—a number of Italian observers had demonstrated beyond a possibility of contradiction the fact that the disease could be transmitted by the bites of mosquitoes with mathematical accuracy, and Patrick Manson of London, wishing to demonstrate this more impressively, arranged that Dr. Bignami of Rome should send him, I think, two mosquitoes which had bitten a case of malarial fever at such a stage that they ought to be capable of transferring it shortly after arriving in London. These mosquitoes were forwarded to London, and his son allowed himself to be bitten by them. His son had never had malaria fever, which does not exist in London today except as in so far as it is im-

ported; and he developed after a proper period of incubation the characteristic symptoms of Tertian malaria of the same type as that which the patient had who was bitten by the mosquito in Rome. It was simply a dramatic illustration of what the Italians had definitely shown before.

"Q. Is malaria as prevalent in the center of a large city as in the suburbs of a large city?

"A. No, there are probably very few if any large cities with proper drainage in which the mosquito capable of transferring malaria is found, except in the suburbs, for the reason that this class of mosquito lives and breeds in shallow pools containing certain sorts of algae for food, and does not breed in other standing water, in wells and cans, and that sort of thing in which the ordinary house mosquito thrives. In Baltimore, which is surrounded by a malarious country, especially on the side of the bay, the disease never breaks out in the middle of the town, except in individuals who have been exposed in the suburbs, and with a pretty wide experience, I have never found the anopheles except towards the outskirts of the city where there are slowly running streams and pools, in which these mosquitoes breed.

"Q. How long do mosquitoes live?

"A. That varies very much and just how long a mosquito may live is not definitely known but mosquitoes hibernate and live through the winter. The anopheles, for instance, I have found in winter in enormous numbers hanging from the ceilings of cellars and the roofs of barns, where they spend the whole winter. In hot weather, unless you keep proper food for a mosquito and give him plenty of room to fly about, he may die pretty quickly, but I have kept mosquitoes alive for—I think the longest I have ever kept mosquitoes alive was two months. A mosquito has to be fed, as a rule, about every other day in warm weather. In winter they will hang upon the wall or in a dark place for months, hibernating.

"Q. The answer you have just given applies to the malarial mosquito?

"A. Yes.

"Q. What is intermittent fever and its clinical diagnosis?

"A. That is not a very easy question to answer. Intermittent fever is a term—a purely clinical term—describing a form of fever; a fever which has intermissions. Such fevers occur under a great variety of circumstances. The term is very commonly used to describe the regularly intermittent malarial fevers, but used as such it is not an exact scientific term.

"Q. What is remittent fever and its clinical diagnosis?

"A. The same answer really applies to that as to the last question; it describes a type of fever which may exist under all manner of circumstances. It has been used pretty largely to describe fevers occurring in malarious districts, long continued with occasional remissions, and non-resistent to quinine, which were once by a great many people supposed to be malarial in nature, but which are known to be non-malarial, and in a vast majority of instances probably typhoid. The term itself merely describes a type of fever—not a disease.

"Q. What is typhoid malarial fever and its clinical diagnosis?

"A. Typhoid malarial fever is an incorrect term which was introduced shortly after the civil war by Dr. Woodward. I am not perfectly sure it was not introduced during the war—by Dr. Woodward, who edited a valuable part of the Medical and Surgical History of the War of the Rebellion. It was used to describe fevers which were supposed to be due to a combination of the malarial and typhoid poison—fevers which were non-resistent to quinine. At the time when the term first came into use neither the cause of malarial nor of typhoid fever was known, and we did not possess anything like the means of diagnosis which we now have. The term has been entirely abandoned by all competent observers and it is now generally recognized that the disease called typhoid malarial fever—that is, the symptoms classed under the name of typhoid malarial fever represent in the vast majority of instances simply uncompli-

cated typhoid fever. In the statistics of city health departments, which are most carefully looked after, all diagnoses of typho-malarial fever are classed as typhoid fever.

"Q. What is congestive fever and its clinical diagnosis?

"A. I don't know what is meant by congestive fever exactly. That is also purely a symptomatic term. If a person told me that his father or his relative had died of congestive fever, I should think—had he lived in a malarial district—I should suspect that it meant acute pernicious malaria; that is, an acute malignant type of malaria associated with unconsciousness. But congestive fever is a term which means nothing to me—it would simply set me guessing as to what the individual who used the term meant.

"Q. What is simple continued fever and its clinical diagnosis?

"A. Simple continued fever is simply a term used to describe a fever which is not accounted for by the man who uses the term. It is a wholly unscientific term and is a cloak for ignorance.

"Q. Are remittent, intermittent, typho-malarial, congestive and simple continued fevers distinct types of disease, and so recognized by bacteriologists and clinicians?

"A. No, they are not. They are simply terms describing symptoms. I should regard these terms when they appear in vital statistics as representing in the vast majority of cases typhoid fever.

"Assuming that the number of deaths in the annual reports of St. Louis from typhoid fevers and the number of deaths under the head of remittent, etc., fevers in the same reports, I should say unquestionably that the number of deaths reported as occurring from typhoid fever alone in the City of St. Louis do not properly represent, in my opinion, the total number of deaths actually occurring in that city. My reasons are as follows:

"I should say in the first place that a considerable personal experience with cases in which these very diagnoses have been

made have shown me that in almost every instance they represent typhoid fever. I should say, furthermore, that in the fourteen years' experience in the Johns Hopkins Hospital I have never made, and I know that there does not stand on the books, a single diagnosis such as appears in the list which you gave of the remittent, typho-malaria, etc., fevers, and further, from the fact that the deaths from malarial fever itself in this city and in this neighborhood, which is a malarious neighborhood, occur in extremely small proportions, as compared with those of typhoid fever, I should say that in view of all these facts, as well as in view of the fact that in other cities in which these diagnoses used to be made, they have now been abandoned entirely; these cases being all classed as typhoid fever. In view of all these facts, I should feel perfectly certain in my own mind that the great majority of these cases represent typhoid fever. Let me say that in my own experience in the Johns Hopkins Hospital, since the opening of the hospital, I have not been here since the opening of the hospital; I came here the year after it was opened; but I have the statistics of that year. There have been 130 deaths from typhoid fever, just four deaths from malaria and no deaths ascribed to any other causes. Then again, the observations of men of confidence who looked into the conditions during the American-Spanish war show that the diagnosis of typho-malaria or simple continued fevers, or remittent fever, as well as a vast majority of the diagnoses of malarial fever, were incorrect, that the condition was purely and simply typhoid fever.

"Let me add just one more word in regard to the question of malarial fever in particular, and the diagnosis of remittent fever, and all that sort of thing. When a man hands in a diagnosis of remittent fever, it is perfectly safe to say that in the great majority of instances he believes its nature to be malarial. Now, these fevers are—anybody who knows anything about practice in this country knows that a case of remittent fever so diagnosticated is never allowed to go through its course without treatment with quinine, and anybody who

has had sufficient experience with malaria and sufficient knowledge with its nature knows that if those cases were malaria not one of them would die. They would all recover.

"Q. To what do you attribute the failure of these statistics assumed in the foregoing hypothetical question, to properly disclose the number of typhoid fever deaths occurring in the City of St. Louis?

"A. I should attribute it to wrong diagnoses made by physicians in reporting deaths.

"Q. Why is it that the doctors employ the terms remittent, intermittent, typho-malarial, congestive and simple continued fevers, for fevers that are recognized as being either typhoid or malarial?

"A. The answer to that will be rather long. It is rather hard to answer in a few words. It seems to me that in the first place it is fair to preface this answer by saying that our knowledge of the nature of malaria and typhoid fever dates in the former instance from '80, and in the latter from '85—that while the discovery of the malarial parasite was made in 1880 and of the typhoid bacillus in 1885, these causes were not generally recognized until at a considerably later period, so that many men in the practice of medicine who are in parts of the world or under conditions where they do not follow well the advances of medicine, and many other men who have begun early to grow mentally old in parts of the world where they could perfectly well keep up with the times, are not familiar with the advances that have taken place. I think, however, that the great cause lies in the fact that we have in this country no fixed laws governing medical education. In only a very small proportion of the medical schools of this country are men required to have actual clinical experience in the diagnosis of these diseases before they graduate; and I think it is perfectly safe to say that the great majority of young men graduating from medical schools to-day in this country have never followed a case of typhoid fever from beginning to end.

"Now, it is perfectly impossible to correctly learn to recog-

nize typhoid fever without actual bedside experience. In the great majority of medical schools in this country medicine is taught practically by lectures and books. The students do not have the necessary clinical or pathological experience—they do not know the nature of the disease, and they have no experience in observing its clinical course. When they go out into practice a large proportion of the physicians of this country have not been trained and are not able to reason out the nature of the problems before them. When they approach the question of diagnosis of a case of typhoid fever, it is to such men simply a question of matching pictures—they are comparing the pictures they see in bed before them with a picture which has been impressed upon their minds by the lectures or by books which they have read. Now, a man fifteen years ago who was told by his instructor that typhoid fever had certain characteristics, and these various other kinds of fevers, which, with the advances of our knowledge, we know do not exist as entities, have other characteristics, and has had few opportunities to control the statements, is very likely to go through his life comparing all that he meets with these pictures impressed upon his mind fifteen years before. An example of this sort of thing—and it is an example for the necessity of having proper clinical experiments—I have mentioned in an address which I made before the Massachusetts Medical Society a few years ago. A young man, who was not stupid, had graduated at one of the better medical colleges of this country—he had been taught the technique of the physical diagnoses very well; he knew how to detect a patch of pneumonia as well as the next man. He entered into the service of a large hospital in one of the largest cities of this country immediately after graduation. He had never in the medical school followed a case of pneumonia from beginning to end, although he had seen a fair number of cases of typhoid fever; he had never followed one from beginning to end. Shortly after the beginning of his services a patient was brought in very ill, who, on examination, showed a patch of consolidation in one of his lungs, clearly pneumonia. The

patient was dull, had oedema of the lungs and was passing a very small quantity of urine, which contained a considerable amount of albumen. The young man had recognized the patch of pneumonia, but the clinical picture which was characteristic was unfamiliar to him. The small quantity of urine and the albumen present led him to believe that it was an instance of Bright's disease, and that the pneumonia was a secondary affair. He was unfortunately left to himself in the treatment of the case and pursued a course of treatment which certainly did not tend to prevent the death of the patient, which occurred shortly afterwards. Now, the picture presented by that patient was perfectly characteristic. Had the student been obliged, as students in England, France and Germany are, to spend a year of his school work practicing in the wards of a hospital, he would have recognized the conditions as easily as possible; as it was he could not grasp the general picture and was led astray. Our standards of medical education are gradually improving, but it is still true in many instances that young men are turned loose upon the public without the practical experience which is necessary—not only for treatment, but for the recognition of disease.

"Q. Do you know of any city in the country where the death rate from malarial fever alone is as high as in the City of St. Louis, as evidenced by the number of deaths, as assumed in the hypothetical question, under the heading intermittent, remittent, typho-malaria, congestive and simple continued fevers, occurring in the reports of the Board of Health of the City of St. Louis, assuming the fevers under those headings to be malaria and not typhoid?

"A. In connection with that question, I may say that I looked up a few days ago the statistics of several cities with regard to that point, and have found some rather interesting facts. I looked up the statistics of the cities of New York, Brooklyn, Philadelphia and of Baltimore. I obtained these from printed copies of the reports of the Boards of Health of these cities, which I obtained from the Surgeon General's library in Washington.

"The mortality for Brooklyn shows some very interesting points. I have here the records of mortality from typhoid and malaria for every year from 1876 to 1903. In 1876 there were reported 97 deaths from typhoid and from malaria 137. Gradually the number of deaths from typhoid tended to increase, while those from malaria tended to diminish. In 1889, for instance, there were 161 deaths from typhoid and 182 from malaria. In 1890 there were 182 deaths from typhoid and 186 from malaria. In 1896 there were 163 from typhoid and 148 from malaria. In 1898, 270 from typhoid and 90 from malaria; and finally, in 1903, I find 267 from typhoid and 36 from malaria fever, showing that while in years past the deaths from malaria fever were relatively as high as those reported in St. Louis, gradually the deaths from typhoid had increased and the deaths from malaria had diminished. The proportion of deaths from typhoid to the deaths from malaria was in 1890 as 1.08:1; in 1903, 7.4:1.

"Now, in the City of New York we find a similar change, though there the deaths from all cases reported as typho-malaria in 1890 were classed as typhoid. In New York in 1890 there were 352 deaths from typhoid and 176 from malaria; in 1900, 342 from typhoid and 68 from malaria; in 1901, 380 from typhoid to 49 from malaria; in 1902, 366 from typhoid to 52 from malaria; and in 1903, 317 from typhoid to 27 from malaria.

"That is the proportion of deaths from typhoid as compared with the proportion of deaths from malaria—in 1890 as 2:1, and in 1903 as 11.7:1.

"Now, in Baltimore a very similar state of things exists. In Baltimore I was unable to get the statistics for 1890. In 1891 there occurred 150 deaths from typhoid fever, from malarial fever 26, and from these other classes of fevers, including 39 'typho-malaria', 65. Since 1897 all the 'typho-malarias' have been classed as typhoid. I do not believe I am justified in saying that positively; I think that is the case. Since 1898 all these nondescripts supposed to be malarial fevers have been

classed under the bad heading of intermittent fever. I find in 1899 the proportion of typhoids to these nondescripts is 153 to 48. There is no special heading of 'malarial fever'. In 1900, 189 to 54; 1901, 146 to 36; 1902, 220 to 31. I was unable to get these statistics for 1903. You see, there again the same change; relatively more diagnosis of typhoid fever and very much less of the others.

"Lastly, I looked up the statistics of the City of Philadelphia. These are interesting, in that in Philadelphia the statistics have been much more carefully controlled. The fevers there are included under three headings: the typhoids, the malarias and another group which are entered in their records as 'intermittent fevers', 'catarrhal' and 'gastric fevers' and so forth. There are one or two deaths every year under these headings; these are, I believe—I am personally convinced—typhoid fever; however, I have made these three headings. In 1890 there were 666 deaths from typhoid fever to 34 from malaria, and 24 of these indeterminate fevers, including 14 cases of remittent fever.

"In 1901 there were 444 cases of typhoid fever, 15 of malaria and 12 of indeterminate fevers. The relative proportion between the diagnoses of typhoid and of the indeterminate fevers, including malaria, was as 11.4:1, in 1890, and as 16.4:1 in 1903.

"During the whole of the fourteen years since the opening of the Johns Hopkins Hospital—or nearly fifteen years now—there have occurred, as I stated before, 130 deaths from typhoid fever and 4 from malaria, the relative proportion being as 32.5:1.

"As one compares these statistics with the statistics of St. Louis, it will be found that those of Brooklyn show at certain times even a larger proportion of the so-called malarial fevers than were present in St. Louis, but that the same change has taken place here as has occurred in St. Louis—the diagnoses of malarial have diminished and the diagnoses of typhoid fever relatively increased.

"I should say that a perfectly safe estimate under the typho-malaria fever column in the St. Louis Board of Health reports would be to classify at least seven-eighths of the deaths under typho-malaria as typhoid fever. If one desired to get the relevant frequency of typhoid fever from year to year, I think the adding together of the two columns would give as correct an idea as any other method. The other one-eighth, I should think, would be a fair allowance for the cases of general tuberculosis or ulcerative endocarditis, and other general septicaemias of various origin.

"There are no cities in this country which give really an accurate representation of the proportion of deaths from malaria. The City of Philadelphia would seem to me to give the fairest representation of this question, and that I have already quoted, where the deaths from typhoid fever in 1901 were 444, from malaria 15 and from various other indeterminate conditions 12. I believe the proportion of deaths is too large, even there, but it approaches the correct figures much more, I believe, than any other city which I have examined. In Baltimore we have in 1902, 220 deaths from typhoid fever and 31 from intermittent fever, which is supposed to be malaria. I am sure from my observations here that that is an overestimate of the deaths from malaria—from my observations which have been made in connection with the Johns Hopkins Hospital, where we get a fair general run of cases as they enter the hospital.

"It is recognized by all competent observers that such a method of representing the mortality from typhoid fever by classifying fevers under these two headings is entirely incorrect.

"Assuming the typhoid and malaria statistics as they appear in the tables from the Board of Health reports of the City of St. Louis from 1895 to 1903, I should regard these tables as indicating that the mortality from typhoid fever had fluctuated more or less from year to year; that gradually in the last three years an improvement in the accuracy in the reports from the general physicians had taken place, so that cases of

typhoid fever which had previously been included in column 'B' (malaria) had been properly treated as typhoid fever.

"As to the relative frequency of typhoid fever and malaria, it would seem to me that it would be impossible to draw definite conclusions from these tables. However, as to the prevalency of typhoid fever, I should think that one might draw good conclusions. I should think that the mortality from typhoid fever had varied from time to time, from year to year; had risen slightly during the last two years, but that the fluctuations were no more than such as has previously occurred and were not such as to justify any direct assumption in regard to the cause. In the year 1892 I should suspect that there had been some definite epidemic, but since that time the variations shown are not such as to suggest to me any direct and special cause. They are variations such as occur in most cities in this country from time to time without exception.

"By combining the typhoid and typho-malaria fevers into totals, as in the table assumed in the question, I should regard this table as indicating only variations in the typhoid mortality, such as I have stated a moment ago, might and do occur in many cities without any definite explanation being found. The typhoid mortality, I should say, rather decreased, tended on the whole to decrease from 1893 down to 1901. During the two years following 1901 there has been a slight increase, but that increase is not, it seems to me, more than might occur without any special change in the pre-existing conditions.

"The circular letter assumed in the question as being sent out to the doctors of St. Louis, I should say that it certainly did manifest itself in the statistics. It appears in the relative increase in the number of deaths reported in the typhoid column, as compared with those in the column of remittent, intermittent, etc., fevers. It would indicate to me that, stimulated by the advice of the Board of Health, the physicians had made more accurate and careful diagnoses. Taking these two columns separately, I do not think they correctly show the typhoid conditions satisfactorily in the City of St. Louis. This is based

upon the fact I have already mentioned, namely, that everything in my experience and study goes to show that the diseases included under such headings as these are, in the vast majority of instances, are typhoid fever.

"In regard to the wells in St. Louis, I should say that the chances were that they would cause typhoid fever; that such wells would be a menace to the health of the city, and that it would be very possible that certain of the wells might become infected and serve to spread the disease. In those cases in which the infection of water supplies have been definite or fairly definitely proved, it is always, to my knowledge, manifested by an explosive epidemic. It is common to assume in cities—such, for instance, as the City of Baltimore, where we know our water supply is open to contamination—it is common to assume that cases are dependent upon the water supply, but as a general rule, where it can be proven that the water supply going to the whole city is infected, there is an explosive outbreak, and it seems to me it would be very difficult to prove the instrumentality of the general water supply to a city in producing typhoid fever unless such an epidemic occurred.

"From a study of the typhoid statistics in St. Louis, they do not indicate an explosive epidemic within the meaning of the answer which I have just given.

"Assuming the combination of typhoid fever and malarial fever, based upon the population of St. Louis, as given in Professor Jordan's table, I should say that this table indicated that during the past two years there has been a slight increase in the typhoid mortality, but that this increase has been preceded by a diminution, and on the whole a gradual diminution from 1892 down to 1901. I should hesitate from these figures to assert that the mortality had prominently increased, or I might say that to look at such a table I should not regard it as having greatly increased, and I should want to see what happens in 1904 before expressing any opinion. The increase in 1902 and 1903 seems to me not more than might occur with fluctuations such as are observed in the tables which I have

mentioned for New York, Brooklyn and other cities. It seems to me that the conditions between 1898 and 1899 are worse than the conditions between 1900 and 1901.

"From a careful analysis of the statistics of conditions since 1900 for the ten years previous, there seems to me to have been an increase, not a great increase, but an increase. There is nothing in those figures to suggest to me any definite special cause. I must say that I should be inclined—perhaps this is quibbling—to regard in any city with a typhoid mortality such as St. Louis has, or that which we have in Baltimore, to regard typhoid fever as epidemic, but I should not consider the conditions of the last several years in St. Louis such as to suggest that any striking change had taken place in the general conditions that obtained prior to that time. I think it is fair to say that any increase occurring two years in succession should always make one look for something, but I should not regard it as particularly suggestive that the assumptions made in the earlier question in regard to the condition of wells in the City of St. Louis are true."

Cross-Examination.

"Between the years 1896 and 1897 there is an increase of a little over 1 per cent., but, of course, between 1898 and 1899 there is a definite increase. There is an increase which is comparable with that which occurred between 1902 and 1903.

"I have seen cases of remittent and intermittent fever which were so diagnosticated and were malaria, but people do not die of it. They are cured by quinine. I have seen such cases that do not react with quinine; in a great majority of instances these have been typhoid fever and never malaria." (7466 to 7501.)

Upon this subject of the wrong classification of diseases under these various heads as they appear in the Board of Health report, Professor Theobald Smith, in his testimony, gave his views, which are as follows:

"Q. Have you made a special study of the so-called germ tests?

"A. I have for twenty years.

"Q. Have you made any study of typhoid fever and malarial fever from the standpoint of a bacteriologist and clinician?

"A. I have made very extensive studies in the agglutination tests for typhoid, which is one of our newest and most reliable tests in the diagnosis of typhoid fever, and I have for a number of years studied conditions that favor malaria in the State of Massachusetts.

"Q. In connection with such study as you have detailed, have you taken up the question of the proper diagnosis of the fevers of the kinds known as typhoid and malarial?

"A. We have in our State. The diagnosis for typhoid and malaria is made free by the State, at the State laboratory, and any physician can send any specimens of blood, prepared in certain ways, for diagnosis, and we advise all physicians to use these methods of diagnosis in order to increase the accuracy of their diagnostic work.

"Q. How about malaria?

"A. Malaria can, as a rule, be recognized by the examination of the blood by a microscope. Now and then this is impossible, but it is usually impossible where the cases are chronic and where the patients have had repeated attacks of malaria. As a rule the diagnosis by means of the microscope is successful.

"Q. Is malaria a fatal disease north of the tropics?

"A. It is not so in our State. There were only two cases which I recall during my eight years of observation in Massachusetts. There may have been others, but those two I recall because I was investigating cases at the time. One was that of an old miser who lived by himself. He had been thoroughly neglected for some time and died without any medical care, and the other was the case of a girl who died in convulsions, I think, and the blood sent to me after death showed malaria parasites, although the blood examination after death is not so satisfactory as that in life. Those are the only two cases I recall in the State of Massachusetts.

"Q. Are remittent, intermittent, typho-malaria, congestive and simple continued fevers distinct types of disease and so recognized by bacteriologists and clinicians?

"A. It is very rare that typhoid fever and malarial fever co-exist, and these cases are so rare as generally to go on record in medical publications. These terms, and especially the term remittent fever, figured quite extensively in medical publications about twenty years ago, but since that time it has almost wholly disappeared, because of the more accurate means of diagnosis.

"Q. Is it generally recognized by bacteriologists and clinicians that classifying typhoid fever in one column and intermittent, remittent and typho-malaria, congestive and simple continued fevers in another column, in boards of health reports of cities, is an improper classification from a scientific standpoint, as affording a true indication of the mortality from typhoid fever and malarial fever?

"A. It is at least a very indefinite form of classification, because we would assume that under the terms remittent and simple continued and typho-malarial we would have either one or the other disease, either typhoid or malaria, or a mixture of the two, which rarely occurs.

"Q. Where such classifications occur, showing almost an equal number of cases under the typho-malarial group with those in the typhoid column, would such a classification furnish a correct idea of the prevalence of typhoid fever in a given community?

"A. I do not think that it would. The classification as you have mentioned it would indicate that the best means of diagnosis were not resorted to in determining the nature of those diseases. (7305-7307.)

In addition to the foregoing testimony upon this subject that the doctors in St. Louis made serious mistakes in the diagnosis of typhoid fever, as evidenced by the table of typho-malaria, etc., as the same appears in the published reports of the Board of Health of St. Louis, and that there has been a trans-

ference of deaths from the malarial column to the typhoid column since 1900, and that the letter sent out by the Commissioner of the Board of Health manifested itself in the mortality statistics of St. Louis no one can deny. This position is supported and sustained by the testimony of witnesses called in this case, not only in chief by complainant, but the doctors who reside in the City of St. Louis corroborate in a remarkable degree the testimony of the experts whose testimony has heretofore been quoted, as reference to their testimony will show.

Dr. William C. Woodward, Health Officer of the District of Columbia, Washington, D. C., called by the complainant in this case, testified as follows in answer to the following question:

"Q. What is the difference between typhoid fever and typho-malaria?

"A. I regard a case of typho-malarial fever as a case of typhoid fever in which the physician has made a mistake in the beginning and called it malarial fever, and he seeks the best way he can to get out of the hole. We classify them separately because some people regard them as different diseases, and we furnish our statistics to people and let them use them as they see fit. I have expressed my opinion. There is a very marked distinction between malarial fever and the other diseases unless you regard the typho-malarial fever as typhoid fever. When it comes to typho-malaria and typhoid fever, the best authorities to-day, I believe, regard them as the same disease." (2887.)

Even Professor Sedgwick, in his testimony, among other things, stated:

"The reports of physicians cannot be absolutely relied upon and the recording of the deaths cannot be absolutely relied upon. It is a choice between two methods, and on the whole I prefer this one and have usually employed it." (2295.)

And again, in reply to the question:

"Q. If it should appear that there were 788 cases of typhoid in the City of St. Louis in 1893, would that be a normal rate while there would be only 215 deaths?

"A. That would not be a normal number of cases; it would be too small. The presumable number of cases from that number of deaths would be nearer 1,500 to 2,000, and all that means is *that the physicians did not report the cases as often happens in epidemics of typhoid fever. They fail to report the cases as they should do, and only the more careful physicians do that. The upshot is that we sometimes get a tremendous fatality when, as a matter of fact, it is about normal.*" (2328.)

Dr. Edward W. Saunders, a resident physician of St. Louis for twenty-six years, was called in rebuttal by complainant, and on cross-examination testified as follows:

"Q. If it should appear in the Board of Health statistics of the City of St. Louis during the last ten years that they have a group of deaths reported as remittent, intermittent, typho-malaria, congestive and simple continued fever, and that those deaths amount to something like two hundred, would that be any reflection upon the doctors of St. Louis in their diagnosis of diseases of that character?

"A. Yes, sir. I think the number is a reflection on the diagnosis.

"Q. And does not the number of deaths so characterized in the Board of Health reports reflect upon the diagnostic ability and carefulness of the doctors who make those reports?

"A. Yes, sir.

"Q. And if the number of deaths appearing in the typhoid death column and the number of deaths appearing in the remittent, intermittent, typho-malaria, congestive and simple continued fever column were about the same, what value would you attach to the statistics as giving evidence of the typhoid conditions in St. Louis, based upon the typhoid fever death column as they appear in those statistics?

"A. Well, I should say that the majority of those cases belonged to the typhoid column.

"Q. Would you say that the doctors in St. Louis were employing the Widal test generally, if such a condition obtained

as evidenced by the compilation of the Board of Health of the city during the last eight years?

"A. No, sir, I should say they were not.

"Q. Is it not a fact that these practitioners wedded to calomel and quinine are obstinate in accepting new treatment for diseases?

"A. That is the tendency.

"Q. Assuming that the mortality health reports of the City of St. Louis disclose the number of deaths from remittent, intermittent, typho-malaria, congestive and simple continued fevers during the last ten years to be about equal to those of the typhoid deaths, is there, in your opinion, any more integrity in the reports of the physicians as to the typhoid deaths than there would be upon the remittent, intermittent, typho-malaria, congestive and simple continued fever death column?

"A. Well, that is a hard question to answer. I would say perhaps the typhoid column is as inaccurate as the other column. That is just a guess or opinion.

"Q. If the typhoid column is as inaccurate as the other column, to what to you attribute the inaccuracies?

"A. To failure in diagnosis.

"Q. Assuming that a circular should have been sent out in the City of St. Louis to all of the 1,600 doctors, local practicing physicians, and assume also that the public press was discussing the question and the effect of the Drainage Canal upon the water supply of the City of St. Louis, and assume that the remittent, intermittent, typho-malarial, congestive and simple continued fever column might decrease during the three years, and the typhoid column increase, would the fact of such an increase be manifest in the statistics of the Board of Health, in your judgment?

"A. If those are all the facts upon which I am to base this judgment, I would say, yes. I do not know that I have all the facts." (7601-7611.)

Dr. Washington E. Fishel, a practicing physician in St. Louis since 1874, called in rebuttal by complainant, testified on cross-examination as follows:

"Q. How would you account, Doctor, for the number of deaths under the heading remittent, etc., fevers, as evidenced by the Board of Health reports prior to January 1900?

"A. That would be purely speculative, if I answered that. I think many of these cases may have been tuberculosis. * * *

"Q. Taking the number of intermittent, remittent and typho-malarial deaths that have appeared in the Board of Health reports of the City of St. Louis during the last six or eight years, would you say that those did not represent more typhoid than consumption?

"A. I believe they represent more typhoid than consumption.

"Q. The number of deaths as represented by typhoid would be a very small percentage of those prior to 1900, would it not?

"A. Yes. I think that is probably correct.

"Q. Now, if the circular after the opening of the Drainage Canal could have an effect upon you, a doctor of recognized standing in the profession, to be more careful in your diagnosis of typhoid, would it not have an equal effect upon doctors less qualified and competent than yourself in reporting typhoid cases?

"A. I think on the whole it has made the physicians of this city more careful in reporting typhoid fever.

"Q. And if the Board of Health reports should disclose that the number of typhoid fever deaths have increased since the opening of the Drainage Canal, and the number of intermittent, etc., deaths have decreased since the opening of the canal, that would evidence the effect of that letter after the opening of the canal upon the physicians of the city in making more careful diagnoses, not only of typhoid fever, but of other diseases, would it not?

"A. It certainly would of typhoid fever, and I think of other diseases. I think physicians are more careful than they have been. * * * I think in regard to typhoid fever the chief reason for their having become more careful was the

penalty attached by the Board of Health in case physicians did not report typhoid fever.

"Q. And when you find a number of deaths aggregating in the neighborhood of 200 in a city the size of St. Louis, reported under the heading of intermittent, etc., fevers, does not that lead you to the conclusion that there are a great number of doctors in the City of St. Louis, the same as in every other large city, that are not abreast of the profession?

"A. Certainly." (7620 to 7623.)

Dr. Ludwig Bremer, a practicing physician of St. Louis, called in rebuttal, on cross-examination testified as follows:

"I have made no comparison of the typhoid fever statistics of the City Health Department of the City of St. Louis for the last eight years. Typhoid fever in St. Louis is not distributed in all localities. It may appear in some localities more frequent, and absent in others, and it may be due to local causes. In figuring out the question of increase of typhoid fever, based upon my impressions, I did not take into consideration the increase in population during the last four years, due to the influx of people here attending the Louisiana Purchase Exposition. That might be included as a factor, I think.

"Q. In the diagnosis of typhoid fever, do you use the Widal test in all cases that you treat?

"A. I never employ the Widal test myself now.

"Q. Those fevers which are called by doctors as remittent, intermittent, typho-malaria, congestive and simple continued fevers, if diagnosticated according to modern conditions and advanced medical learning, would be classified either as malaria or typhoid fever, would they not, in the majority of cases?

"A. I would not say that with such a precision. I would say that, no doubt a number of these cases have been typhoid, being entirely unrecognized cases or mistaken cases of typhoid. I do not know what percentage." (7626, 7632.)

Dr. Albert E. Taussig, a practicing physician of St. Louis, testified on cross-examination as follows:

"Q. If such a proportion of deaths should be wrongfully

diagnosed as intermittent, etc., fevers, as is evidenced from the Board of Health reports, would not such a diagnosis reflect upon the ability of the physicians sending in such causes of deaths from diseases which could be properly diagnosed if they had sufficient skill to do it?

"A. Why, certainly.

"Q. If the doctors would diagnose tuberculosis under the heading of intermittent, remittent, congestive and simple continued fevers, why would they not diagnose typhoid fever under that head, the same class of doctors?

"A. I do not think they are very apt to diagnose death from tuberculosis under those heads. Ordinarily, when a patient dies of that disease it is pretty clear. I hardly think any really first-rate man would be apt to use those terms, for he would be conscious of their ambiguity. It would be used by the physicians who are not up to date, and all physicians of St. Louis are not up to date." (7644 to 7653.)

Dr. Charles H. Goodman, a practicing physician of St. Louis, on cross-examination testified as follows:

"I do not recognize intermittent, remittent, typho-malaria and congestive and simple continued fevers as distinct types of disease. (7666.)

"Q. It may be typhoid, it may be malaria or some other disease which has a remittent, intermittent, congestive or simple continued fever symptom?

"A. Yes, sir.

"Q. What other diseases are as prevalent in the City of St. Louis as malaria and typhoid that possess these symptoms?

"A. None that I know of.

"Q. If in the health reports of the City of St. Louis there should appear tabulated as deaths occurring from intermittent, etc., fevers, a number of deaths in excess of the number of deaths from typhoid fever, and as you state it, you do not regard intermittent, remittent, etc., fevers as distinct types of disease, what, in your opinion, did the people so charged with

dying under the head of intermittent, remittent, typho-malaria fevers die of?

"A. They might have died of typhoid fever; they must have been confounding the terms, or confounding the diagnosis of cases, I should think. I do not know of any such fatality from malarial fever.

"Q. In comparing the groups of typhoid with the typho-malaria, etc., do not those statistics show that the doctors, in reporting typhoid conditions in the City of St. Louis, reported cases of typhoid fever deaths under the typho-malaria group?

"A. Yes, I believe they did at that time.

"Q. Since that time, in the number of deaths appearing as being reported by the physicians of St. Louis to the Health Department under the heading typho-malaria, remittent, intermittent, congestive and simple continued fevers, can those fevers be accounted for in any other way than that typhoid fever had been wrongly diagnosed as something else, and so reported, in your opinion, assuming that the figures that we have collected have been sworn to and verified as true in the record?

"A. Well, as far as they are true, I certainly do, on the supposition that these figures were correct; I will say that the reports may have confounded diseases; those that were reported as typho-malaria might have been typhoid or typho-malaria, congestive, remittent or intermittent.

"Q. But assuming that these statistics that I have collected are properly compiled from the reports of physicians placed in the Health Department of the City of St. Louis and published in their official reports?

"A. Yes, sir.

"Q. Can the number of deaths reported under the heading of intermittent, etc., fevers be accounted for in any other way than that typhoid fever has been wrongfully diagnosed under these various headings?

"A. No, sir.

"Q. Now, while that letter sent out by the Board of Health

had no effect upon you, are you prepared to state that it had no effect upon any of the doctors that practice in the City of St. Louis?

"A. No, sir.

"Q. Assuming the typhoid conditions and typho-malaria conditions in 1896 to 1903, can you account for the decrease in the typho-malaria column and the increase in the typhoid fever column since 1900 in any way except that the fevers which had heretofore been diagnosed as intermittent, etc., have been diagnosed as typhoid fever and placed in the typhoid fever column, when heretofore they were placed in the typho-malaria column prior to 1900?

"A. No, sir." (7666 to 7672.)

The testimony hereinabove quoted, not only from the witnesses called on the part of the defendants, but also the witnesses called by the complainant, proves conclusively beyond a reasonable doubt that the diseases known as intermittent, remittent, typho-malarial, congestive and simple continued fevers are not distinct types of disease, so recognized and classified by the leading physicians of this country, but are in reality typhoid fever. And the evidence further shows conclusively that the number of deaths reported in the published reports of the City of St. Louis under the heading of typhoid fever do not correctly disclose the true typhoid conditions existing in St. Louis prior to or since 1900. If the evidence in this case, as hereinbefore cited, and which defendants contend has not been contradicted in any way by any reputable witness in this case, establishes the facts conclusively that the number of deaths reported under the typhoid column does not show the real typhoid conditions in the City of St. Louis prior to and subsequent to 1900, the testimony of the witnesses called on the part of complainant to establish its case is based upon a false premise, is misleading and not well founded, and any conclusions based upon typhoid conditions, as evidenced by the table of deaths under the heading of typhoid fever, as the same appears in the published reports of the Board of Health

of the City of St. Louis, are not worthy of consideration, for the reason that if the premise from which the conclusion is drawn is false it follows necessarily that the conclusion is wrong also. The defendants in this case contend that the evidence heretofore quoted proves conclusively, beyond all reasonable doubt, that the letter sent out by the Board of Health of the City of St. Louis at the time that the Drainage Canal was opened manifested itself in a more accurate diagnosis of typhoid fever than had existed heretofore, and this resulted in transferring to the typhoid death column deaths which heretofore had been classified under the heading of intermittent, remittent, typho-malarial, congestive or simple continued fever.

The evidence in this case establishes affirmatively, beyond all reasonable doubt, that when properly compiled and analyzed the typhoid fever statistics of the City of St. Louis, as shown in its published Board of Health reports, do not disclose any real increase of typhoid fever, or at most a doubting and halting one, such as might be expected in a World's Fair city, with a considerable influx of population and numerous and continued sources of infection. No explosive outburst of typhoid fever such as characterizes water borne epidemics, followed the opening of the Chicago Drainage Canal.

Infancy and Old Age Not Exempt from Typhoid Fever.

It has been attempted in this case to establish as a fact that infancy and old age are not subject to typhoid fever. The defendants in this case offered no evidence upon that proposition, believing that the evidence of complainant's witnesses was sufficient to demonstrate that typhoid fever is not a respecter of age. Dr. Herbert E. Smith was asked this question:

"Q. Doctor, at what ages do most of the deaths from typhoid fever occur?

"A. The ages of most susceptibility from typhoid fever are from fifteen to thirty, though there are many cases between ten

and forty, the cases under ten and over forty being less common than in the other decades.

"Q. Is not the disease rare in infants and persons over sixty years of age?

"A. Yes, sir, the disease is comparatively rare at these ages." (7722.)

This testimony of Dr. Smith does not show affirmatively that infants and persons over sixty years of age are immune or exempt from typhoid fever.

The testimony of practicing physicians in this case, called on the part of the complainant, is worthy of consideration in this connection.

Dr. Edward Saunders testified, page 7596, as follows:

"I have no more clear conception of bilious fever than I have of a congestive fever. The same is true of malaria, but of simple continued fevers I would say that they were all in the typhoid class.

"Q. Unless the patient be an infant?

"A. Well, no, I would not even make that qualification, for the reason that a fever which continues any length of time, if it be malaria, is amenable to quinine, and if not amenable to quinine, I believe in the Osler dictum that any fever that continues a week and is not amenable to quinine and is not anything else, is typhoid." (7596.)

Dr. Washington E. Fischel, another of complainant's witnesses, testified, on page 7614, on direct examination, as follows:

"Q. Doctor, do infants and old people die of typhoid fever?

"A. Yes, sir, that does happen.

"Q. Is it prevalent among infants and old people?

"A. No.

"Q. At these ages?

"A. Not as compared to other ages."

Dr. Albert E. Taussig, another of complainant's witnesses, was asked this question on re-direct examination (7655):

"Q. At what ages are persons most likely to contract typhoid fever?

"A. On the whole, it is a disease of maturity and middle age, though both the very old and the very young do have it. Just how frequent it is in infancy is still a matter of considerable dispute."

The foregoing testimony in this case, all of which was offered by complainant, failed to show that typhoid fever is a respecter of age, but the conclusion, to use the expression of Dr. Taussig, as to "just how frequent it is in infancy, is still a matter of considerable dispute".

X.

THE EVIDENCE IN THIS CASE ESTABLISHES AFFIRMATIVELY BY A PREPONDERANCE OF EVIDENCE THE FOLLOWING PROPOSITIONS:

(A) THE TYPHOID GERMS ENTERING THE SEWERS OF CHICAGO WILL NOT SURVIVE THE JOURNEY TO THE INTAKE TOWER OF THE CITY OF ST. LOUIS IN A VIRULENT CONDITION AND BE ABLE TO CAUSE TYPHOID FEVER AMONG THE INHABITANTS OF THE CITY OF ST. LOUIS.

(B) THE TYPHOID GERMS FROM CHICAGO WILL NOT MAKE THE JOURNEY TO THE MISSISSIPPI RIVER AND BECOME A DANGER AND A MENACE TO THE INHABITANTS OF THE STATE OF MISSOURI TAKING THEIR WATER SUPPLY FROM THE WATERS OF THE MISSISSIPPI RIVER.

(C) THE OPENING OF THE DRAINAGE CANAL IS NOT A DANGER AND A MENACE, PRESENT OR IMPENDING, TO THE INHABITANTS OF THE STATE OF MISSOURI TAKING THEIR WATER SUPPLY FROM THE MISSISSIPPI RIVER.

(D) A TYPHOID GERM LEAVING THE SEWERS OF CHICAGO BY WAY OF THE DRAINAGE CANAL WILL HAVE PERISHED LONG BEFORE GRAFTON IS REACHED ON THE ILLINOIS RIVER.

These four propositions, because of their intimate relationship and the impossibility of separating the evidence, will be treated as one proposition. The testimony in this case offered by the defendants shows conclusively by a preponderance of the evidence that the opening of the Drainage Canal was in no way a danger or a menace to the inhabitants of the State of Missouri. In substantiation of these foregoing propositions, the defendants call attention of the Court to the witnesses who have testified and the testimony that has been given, which, on account of its importance, is set out in great detail.

Professor H. L. Russell has expressed himself as follows:

"Inasmuch as the typhoid organism is incapable of thriving in normal raw waters, or in other waters contaminated with

organic matter, and therefore they are more or less rapidly destroyed and would therefore be present in diminishing numbers the longer they remain in water, there is no evidence that I know of, secured under scientific conditions or otherwise, that would show that the vitality of the typhoid organism would be contained in the sediment of streams which are saturated with water and the soluble substances dissolved in that water for considerable periods of time, and I do not believe that the conditions would ever obtain under a natural state of affairs so that a large number of typhoid organisms would be found present in a stream, a considerable distance from the source of pollution, which were larger than would exist under the original source of such pollution. (6566.)

"Owing to the fact that the pollution or infection which would be deposited in the Illinois River from the sewers of Chicago would be practically purified by the time it has been carried for a portion of its way down the river on the way from Chicago to Grafton, it would naturally follow that the waters of the Illinois River, which entered the Mississippi River at Grafton, would not be a menace to the inhabitants of the Missouri shore of the Mississippi River, if such water was used for drinking purposes at points below on the Missouri shore. (6568.)

"I would not consider that the admission of the waters of the Illinois River * * * would cause any menace to the inhabitants of the Missouri shore when the waters of the Illinois River were discharged into the Mississippi and commingled with the waters of the Missouri River and Mississippi River, and when the waters of the united streams was used for drinking purposes by persons living below Grafton on the Missouri shore. (6569.)

"The chemical and bacteriological evidence which has been secured in this case through the experimental and observational data which have been presented justify, in my judgment, the conclusion that the waters of the Illinois River at Grafton show no indication whatever of unpurified sewage from Chicago that had found its way from Chicago to the latter place." (6569.)

"Taking into consideration the time involved in the flow of water from Chicago to St. Louis, and in view of the evidence which I have previously presented in combination with others, that the typhoid organism is incapable of retaining its vitality for the period of time assumed in the foregoing question, I would say that I know of no evidence based upon any analysis, experiments or otherwise, that would justify the assumption that typhoid organisms deposited in the Chicago Drainage Canal will pass by way of the Illinois River into the Mississippi River and find their way into the water supply of the City of St. Louis at the intake tower at the Chain of Rocks." (6571.)

"In view of the fact that under the conditions which now exist and have existed for the period of the last three years, it is my opinion that the typhoid organism would have been destroyed in a period of time which would comprise only a small portion of the time necessary for water to pass from Chicago to the mouth of the Illinois River, and assuming the increase in population which must also assume an increase in amount of sewage not containing the typhoid organism which would be deposited in the waters of the Drainage Canal, and the taking into consideration the effect which would be produced by such an increase and the influence of conditions as would exist on the basis of the assumption made, it is my opinion that the addition of the sewage coming from the number of people mentioned, discharged into the amount of water mentioned, would not materially alter the conditions which would exist in the waters of the Illinois River at its mouth, so far as these conditions had any effect upon the elimination of those elements in sewage which are of importance in sanitary matters. The addition of this increased amount of sewage would probably alter the amount of soluble substances which would appear in the waters of the Illinois River at its mouth. These would have no effect upon the sanitary condition of such waters." (6574.)

"Taking into consideration the chemical and bacterial

knowledge which has been derived from actual experiment, and also all knowledge which I possess with reference to the conditions which would obtain when the sewage of Chicago was placed in the Drainage Canal, and the taking into consideration the possible variation which would exist at different seasons of the year, and the influence which different stages of water would exert upon the vitality of disease organisms which might be present in such sewage, it is my opinion that the introduction of such sewage into the Illinois River would not be a danger and a menace to the inhabitants of the State of Missouri and the citizens of the City of St. Louis who might use the waters of the Mississippi River at the intake tower, Chain of Rocks." (6575.)

"Taking into consideration the conditions hypothecated, that the sewage of Chicago is discharged in the Drainage Canal at such a distance from the State of Missouri that dangerous pollution coming from the sewage of the City of Chicago, so far as that pollution itself is concerned, would be deprived of its dangerous properties during the period of flow which is necessary for the passage of such sewage from the City of Chicago to the State of Missouri, it is my opinion that the sewage of Chicago, discharged into the Drainage Canal, will have no deleterious effect upon the inhabitants of the State of Missouri using the water of the Mississippi River for drinking purposes." (6580.)

Cholera.

"In view of the fact that all of the evidence, both analytical and otherwise, indicates that the organism capable of producing Asiatic cholera is more sensitive to the influence of external environments than the organisms of typhoid fever, and from the conclusions which have been presented with reference to the vitality of the typhoid organism and their inability to live for a period of time which would be covered by the flow assumed in the question, I should say that it is impossible for the organisms of Asiatic cholera, should they exist in the City of Chicago, to be discharged into the Drainage Canal and then

to find their way down that stream and into the intake tower of the St. Louis waterworks at the Chain of Rocks." (6571.)

Professor F. Robert Zeit testified:

"I do not believe that the Drainage Canal or the sewage entering the Drainage Canal can be of any danger due to pathogenic bacteria remaining in it, to St. Louis or Missouri, for the reasons already stated. My opinion is based mainly on the behavior of pathogenic bacteria in the presence of saprophytes and my opinion is also based on the general knowledge the world over of the existence of a bacterial zone of purification in any river and a continuous and permanent purification as the river flows along. As it flows along new pollution occurs and new bacterial purification zones formed, which is my reason for feeling certain that no pathogenic bacteria entering the sewers of Chicago or the Drainage Canal will pass beyond Averyville, where bacterial purification was complete. This distance is much greater than that which is generally found the world over in every river. I would have liked, of course, very much to have more material, make more examinations, and to determine more positively the exact place of the bacterial purification, which I am quite certain is far above upper Peoria. I wanted to feel safe in saying that the absolute disposal of all pathogenic bacteria had been completed, for the reason that even the saprophytic bacteria and the sewage bacteria have disappeared, and for the reason that, here, practically no bacterial pollution whatever of the river existed." (4474-5.)

"It is my opinion that after that length of time (sixty days) there would be no typhoid bacilli present any more. The conditions existing in material on the bottom of rivers and lakes by sedimentation must contain organic material and saprophytic bacteria, which, again, would produce substances that would destroy the typhoid bacillus if it was present in just as quick a manner as they do in the river or lake water. In fact, I should think that being so much closer in contact with the saprophytic bacteria in the presence of organic material, that the quantity of these poisonous substances produced by sapro-

phytes would be even greater and cause typhoid bacilli to die at least as quick, if not quicker, under these conditions than flowing water." (6440.)

"By what I have learned from the experiments that we have made, that it is impossible for typhoid bacilli coming from the sewers of Chicago, through the Drainage Canal, to be deposited on the bottom of a bed of the Desplaines and Illinois Rivers between Chicago and Peoria, and remain there for a period of from thirty to sixty days, and yet retain their dangerous qualities. Typhoid bacilli die under those conditions in three days. It is my opinion that typhoid bacilli derived from the sewers of Chicago would never reach the intake of St. Louis alive, because it has been proven by our experiments that they die in three days or less in the water of the Drainage Canal and the Illinois River, so that they could never reach the lower course of the Illinois River even." (6441.)

"I do not consider the sewage of Chicago emptying into the Drainage Canal and the Illinois River, which, in turn, empties into the Mississippi River, a menace and a danger to the inhabitants of the State of Missouri using the waters of the Mississippi River for drinking and domestic purposes and to the citizens of the City of St. Louis taking their water from the intake tower at the Chain of Rocks from the Mississippi River."

"I take this position for the reason declared in my former examinations, in which I stated that the Illinois River at Averyville was purer bacterially than any part of its course from Chicago to Grafton, and that I considered that absolute purification from saprophytic as well as pathogenic bacteria had taken place above Averyville." (6442.)

"The contamination produced by the sewage of Chicago would be all practically removed before it reaches Averyville, according to my investigations and answers in this case, in which I have expressed these convictions at some length. I am speaking now, of course, of bacterial purifications and not of chemical substances, but I should judge that also chemical

purification has taken place so as to convert dangerous organic compounds into non-dangerous ones, as soon as saprophytic life has again decreased, and thereby shows that the end products of organic material have been produced by saprophytic multiplication, and I therefore cannot consider this a danger or a menace to the citizens of St. Louis or the citizens of Missouri using the water for drinking and domestic purposes." (6442.)

Professor E. G. Smith testified as follows:

"As a sanitary expert, basing my opinion upon all the information which I possess in this case, such information being derived from the study of the physical properties of the stream from a personal examination of the same throughout its entire length, from the mouth of the Chicago River to the mouth of the Illinois at Grafton, from a study of all bacteriological and chemical data which have been submitted in this case, from a knowledge of the experiments regarding the vitality of the typhoid bacillus, the experiments being carried out in the waters of the Illinois River, after the same has received the sewage of the City of Chicago, by way of the Chicago Drainage Canal, from the rate of flow of the river, from the study of the agencies operative in the self-purification of the stream, consisting of dilution, sedimentation, all chemical and bacteriological changes effected in the same, from the comparison of the data of the waters through the upper reaches of the river, after it has received the sewage of the City of Chicago through the Drainage Canal, the comparison of the results, both bacteriological and chemical, at Averyville, and after the river has received the sewage of the City of Peoria and smaller towns, and the quality of the water of the river, as evidenced by the analyses made at the City of Grafton, near the mouth of the Illinois River, and comparing the same with the data at hand regarding the quality of the Mississippi River and my personal knowledge of the habits of the stream and the sanitary quality of the waters of the same, and from an examination of the data regarding the quality of the Missouri River, I am of the opinion that the water supply of St. Louis is not contami-

nated, polluted or injured by the sewage of Chicago entering the Drainage Canal and thence into the Illinois River." (6812-3.)

"My examination of all data which I have been able to gather together, which bears upon this case, from a study of the tables submitted by witnesses for the defense in this case, from my knowledge of the conditions of the Illinois River throughout its entire length, derived from the personal inspection of the same, from the data regarding the viability of the typhoid germ and the period of time necessary for water to flow from Chicago to St. Louis, and from my study of the agencies operative in the sanitary purification of this stream, from the chemical and bacteriological changes which obtain through the course of its flow, it is my opinion that sewage from the City of Chicago becomes practically purified at Grafton and the quality of the Illinois is fairly comparable with that of streams forming its tributaries, and that the sewage of Chicago has become purified practically, the pathogenic bacteria having been eliminated in the process of flow of the stream, and hence the original organic matter of the sewage from Chicago does not find its way into the intake tower of the St. Louis waterworks at the Chain of Rocks." (6813.)

"From all the knowledge which I have upon the sanitary quality of the Mississippi River after the same has received the waters of the Illinois River, from the fact that the agencies of self-purification of a running stream obtain in the Illinois River, from the fact that in my opinion the waters of the Mississppi River are not of as good a quality as those of the Illinois River before the Illinois River may have found access to the same, because my study of the Illinois River leads me to consider that the sewage as a factor has been practically eliminated from the Illinois River before it empties into the Mississippi River at Grafton, I am of the opinion that the Mississippi River at the intake tower of the St. Louis waterworks at the Chain of Rocks is not less valuable for drinking purposes and it is not more liable to carry water borne diseases,

such as typhoid fever and cholera, now than it was before the sewage of the Sanitary District was run into it." (6814.)

"From all the knowledge which I have been able to obtain about the conditions in the Drainage Canal, the Desplaines River and the Illinois River, the same being based upon personal inspection and analyses, both chemical and bacteriological, already submitted in evidence in this case, from the bacterial purification of the river, as shown by such tables which obtain at Lake Peoria, and especially from the positive results we have in the experiments of Doctors Zeit, Jordan and Russell upon the viability of the typhoid germ in the sewage-laden waters of the Illinois River, the results of such experiments being to show that the typhoid germ lives for a short time in the water of this river, the period being represented by three or four days, it is my opinion that the typhoid fever germs coming from the Chicago sewers would not reach down the Illinois River as far as Peoria, and further, even if such bacteria may be deposited in the sediment of the stream in the course of its passing down the river, the fact that the same has been taken up from the sediment of the river and been subjected to the destructive agencies of the stream, I am further fortified in the opinion that the typhoid bacillus would not reach as far as Lake Peoria, and therefore water leaving Lake Peoria could not possibly contain more infectious and dangerous pollution than are at present in the diluted sewage entering the bear-trap dam at the foot of the Drainage Canal." (6818.)

"The evidence as already introduced in this case, both chemically and bacteriologically, showing, in my opinion, so conclusively that the agencies of self-purification operative in this stream have practically transformed sewagic matters from the City of Chicago before they reach Grafton, reducing the river at that point practically to the condition of the streams tributary to the same, and the positive results secured from the experiments of Doctors Zeit, Jordan and Russell upon the viability of the typhoid fever in the polluted waters of this stream, I do not believe that infectious and dangerous pollu-

tion might under existing conditions find its way into the water supply of St. Louis." (6821-2.)

"From the conditions of the river, the agencies operative in the self-purification of the stream, which, in my opinion, have practically transformed all sewage entering the river from the Drainage Canal when the river reaches Grafton, it is my opinion that the Drainage Canal has not rendered less safe and wholesome the water used for drinking purposes on the part of the inhabitants of St. Louis using the waters of the Mississippi River below the mouth of the Illinois River than they were before the canal was opened." (6824.)

"From the evidence already given in this case, and particularly the positive results of the experiment of Doctors Zeit, Jordan and Russell, in which they have demonstrated that the typhoid germs from the City of Chicago can live but a short period in this sewage laden water, such period covering, according to those observations, perhaps three or four days, it is my opinion that the sewage of Chicago does not favor the longevity of the growth of germs from Peoria or any other city also emptying its sewage into the river, but on the contrary the same agencies which have operated in this river, which have tended to diminish the viability of typhoid fever, would still be operative upon typhoid fever germs coming from points below." (6825.)

"Assuming that the population of Chicago should increase, even to the population of 5,000,000, and the sewage should be discharged into the Drainage Canal and be carried through the Drainage Canal into the Illinois River, and so pass down the river to the Mississippi River, in my opinion the bacterial or the germicidal effects of the water would still be operative and operative in a degree as efficient as they are at present, and inasmuch as the action of the water, bacteriologically and chemically and otherwise, according to the experiments already introduced into this evidence, now destroys the typhoid bacillus at a period not exceeding three or four days, in my opinion it would follow that the causes operative in the river would, even

with a population of 5,000,000, and with a typhoid fever epidemic, obtain so that the sewage from the Sanitary District, discharged into the canal, would not be an immediate and impending danger for the people of St. Louis and the people living on the Missouri side of the Mississippi River using the water of the Mississippi River for drinking purposes." (6826.)

Cholera.

"Q. Assuming that an epidemic of Asiatic cholera should break out in the City of Chicago, is it possible that the germs of that disease might find their way into the intake tower at the St. Louis waterworks at the Chain of Rocks, from the City of Chicago?

"A. It is my opinion that in the event of an outbreak of cholera in the City of Chicago, the germs of that disease could not find their way into the intake tower at the Chain of Rocks of the St. Louis waterworks from the City of Chicago, for the reason the bacterial agencies at work, operative in the purification of the stream, effect a bacterial purification of the Chicago River before Averyville is reached. Regarding the cholera germ, from such knowledge as I have been able to gather concerning it, it is less resistent than the typhoid fever germ, and therefore any agency operating to the removal of a typhoid fever germ would, in my opinion, be more decided than in the case of the typhoid fever germ." (6823.)

Dr. Lewellys F. Barker, of the Chicago University, formerly of Johns Hopkins University, testified upon this subject in part as follows:

"Q. What is your opinion as to whether typhoid bacilli could survive the journey from Chicago to St. Louis, a distance of 357 miles, passing down the Illinois River, passing by Peoria and Pekin, which receives a large discharge of sewage from the cattle sheds of the cities of Peoria and Pekin, Peoria being a city with a population of about 75,000 inhabitants, and getting into the water supply of St. Louis, and causing typhoid fever? (7101.)

"A. There is no evidence in the literature which would make it seem probable indeed. All the evidence that I know would oppose the probability or even possibility of that occurring, and, moreover, the proof that it did occur could not be brought unless every typhoid bacillus now entering the stream between, say, Lockport and St. Louis, could be excluded from the river. In my opinion, typhoid fever bacilli would not survive the journey.

"Q. As an epidemiologist and pathologist, do you consider the sewage of Chicago entering the Drainage Canal and the Illinois River, which in turn empties into the Mississippi River, a menace and a danger to the inhabitants of the State of Missouri, and the citizens of the City of St. Louis taking their water supply from the intake tower at the Chain of Rocks in the Mississippi River?

"A. In my opinion, no.

"Q. If the disease of tetanus should appear in Chicago, what is your opinion, as an epidemiologist and pathologist, as to whether the inhabitants of St. Louis are in danger of infection from tetanus by reason of the operation of the Chicago Drainage Canal?

"A. In my opinion, there would be no danger of infection by tetanus. It doesn't occur in such a way at all.

"Q. From anthrax?

"A. In my opinion there would be no danger.

"Q. From the bacillus enteriditis sporogenes?

"A. There would be no danger in my opinion.

"Q. What is this bacillus enteriditis sporogenes?

"A. I take it that by that you mean the bacillus which is identical with the bacillus aerogenes capsulatus of Welch and Nuttall, a facultative anaerobe which is capable of causing infection in human beings, cases of which I have studied, but which is not, as far as we know, a water borne disease, and, moreover, is a rather rare disease. The bacillus is a spore producing bacillus, but I cannot conceive of cases of the disease occurring in Chicago being a menace in any way to the citizens of St. Louis." (7103.)

And again, on cross-examination, he testified as follows:

"Q. Now, what data have you collected, Doctor? I want to know what specific data you have collected, that would enable you to determine and express an opinion as an epidemiologist, now, upon the sanitary condition of the water in the Illinois River at Averyville?

"A. Well, I have collected a great deal of data upon the self-purification of streams. I have a good deal of general knowledge of bacteriology. I fear this is rather an immodest sort of a statement, but I must do it, as you asked me to.

"Q. That is all right. I want you to make it.

"A. I have gradually accumulated general conceptions about water supplies and sanitation in the course of the last fifteen years in medical work. I have read some of the literature bearing upon the researches upon the conditions of the Illinois River. I have talked with friends before I had any idea of dealing with this case, with regard to the situation, and have formed judgments upon the situation. From all those together, and from my general knowledge of disease, clinical and pathologic, mode and spread of typhoid; from the fact that I have received what I regard as reliable information concerning the existence of typhoid in cities below Chicago on the river, and that the sewage from some of those cities at least, in which typhoid fever exists, is poured into the river. On all these, taken together, I have formed my opinion. (7197.)

"Q. I want to know just exactly what you did get.

"Mr. Todd: Give all details.

"A. Well, as I understand it, the Illinois River receives a number of tributaries, including the Desplaines River and the Fox River and the Kankakee River and the Vermilion River and the Sangamon River and other streams of various sizes, and that these streams come into the river of course at different points. I understand that before the Drainage Canal was constructed that sewage was pumped from the Chicago River into the Illinois and Michigan Canal—I think that is the name of it—and that that canal then emptied that

sewage into the Illinois River, but that since the Drainage Canal was built the Chicago River is more directly connected, without the aid of the pumping station. The sewage is poured into the canal at the upper part of the river. I should know that there are three or four locks on the river; that the stream is not a rapidly flowing stream; that in many parts of the river the rapidity of the flow is very slow. I have understood that it is as low as half a mile in some places, and that the conditions of flow in the stream are different at different times of the year. I have been given to understand that not all the sewage of the City of Chicago goes into the Drainage Canal at present. Part of it still goes into the lake, but that an intercepting sewer is being built to lead more of the sewage into the Drainage Canal. I understood that the current into the lake from the Chicago River before the Drainage Canal was built was a very slight one, and sometimes it almost tended to run the other way, and that the smell from the sewage became objectionable to the city, and that it was believed that the pouring of the Chicago River and its sewage into the lake was a detriment and menace to the city's health, and that the Drainage Canal was built in order to protect the city from this danger, and also from the nuisance. I understood that this cost a great deal of money, many millions of dollars—more than thirty millions, perhaps, of dollars, and I have learned that on the banks of the river there are a number of towns which I have already mentioned. I learned that typhoid fever exists in at least some of those towns, and I have been told by men upon whose opinions I rely that the sewage from some of those towns in which typhoid exists, is poured into the Illinois River, and that there is no adequate protection to either the river bank or the banks of the tributaries of the river, from contamination; that in fact the whole Illinois River is a drainage canal—in one sense it might be regarded as a drainage canal, and a drainage canal that is polluted at a great many different places. Then I have learned that the sewage deposited into the Drainage Canal, and in points below it, had decreased with great rapidity

in the number of bacteria which it contains, and that, of course, that agrees with observations in other places under similar conditions.

I have learned, further, that the stream, as far as chemical and bacteriological analyses permit of a judgment to be formed, purifies itself gradually on the way down, from Chicago to Peoria; that at Lockport and Joliet the contamination of the stream is still very great, probably still greater from the City of Chicago, and at Morris there is still a good deal of contamination in the stream, but that from that point on there is a tolerably rapid, though gradual, diminution in the contamination of the stream as judged by bacteriological and chemical studies of the stream; that when Ottawa is reached there is far less contamination than at Morris. At La Salle the contamination is still less, and that at Henry it is very slight, whereas, at Averyville the conditions are those of an ordinary river water that would ordinarily be regarded as a fairly good water, but that suddenly, below Averyville, at Peoria, the river again becomes very badly polluted from the sewage of that city. Indeed, while at Averyville, a few miles above Peoria, the stream is a tolerably pure river water, even under present conditions, at Wesley, which is just below Peoria, the conditions are practically as bad as they were at Lockport, only thirty miles from Chicago; that this condition is also very bad at Pekin, and in all probability is exaggerated by the sewers poured into the river by Pekin, and below Wesley the river again tends to purify itself, and at Havana there is a remarkable diminution in the phenomena which chemists and bacteriologists regard as polluting phenomena; and at Beardstown still less, and at Kampsville still less, and when Grafton is reached the conditions are very much again like those at Averyville, as far as chemical and bacteriological studies are concerned, and the river compares quite favorably with ordinary river waters. (7197 to 7200.)

"Q. Then I understand you, that from your experience as a bacteriologist and biologist, and from what you have read, and

from what you have just stated with reference to the physical conditions in the Illinois River, as having been obtained by you in talking with others and in reading articles written by others, you, as an epidemiologist, undertake to express an opinion that the water in the Illinois River at Averyville, after receiving the sewage of Chicago and of other cities situated upon that river above Averyville, is in a reasonably safe sanitary condition?

"A. I do." (7201.)

Cholera.

"Q. Assume that an epidemic of Asiatic cholera should break out in the City of Chicago, and the sewage of Chicago should enter the Drainage Canal and the Illinois River, what is your opinion as to whether or not the germ of Asiatic cholera would survive the journey from Chicago to the intake tower at the Chain of Rocks, a distance of 357 miles, and be a menace and a danger to the inhabitants of the citizens of St. Louis?

"A. In my opinion it would not." (7102.)

Professor Arthur W. Palmer, whose untimely death is deplored by all who were associated with him in the conduct of this case, and who showed in his testimony greater familiarity with the conditions prevailing in the Illinois River than any other witness testifying in the case, expressed himself as follows:

"From the knowledge and information which I possess concerning these waters and the conditions existing in and about them, and the results of the investigations which I have made of these waters before and after the opening of the Chicago main drainage channel and the knowledge I have of investigations of these same waters made by others before and after the opening of the Chicago main drainage channel, it is my opinion that the effect of the increased flow secured by the opening of the Chicago main drainage channel has been at times to increase the flow of water in the Mississippi River along the western borders of the State of Illinois and the eastern borders of the State of Missouri, and further, it is my opinion that the increased flow secured by the opening of the Chicago main

drainage channel, containing, as it does, increased quantities of organic matters derived from Chicago sewage, does not injuriously affect the waters of the Mississippi along the eastern borders of the State of Missouri, so far as the use of such waters for domestic, agricultural and manufacturing purposes is concerned, for the reason that the effect of the increased flow secured by the opening of the Chicago main drainage channel has been co-incident with or the cause of more complete destruction of the organic matters introduced into the upper Illinois River to such an extent that the waters discharged by the Illinois at its mouth contain less organic matters than they did prior to the opening of the Chicago main drainage channel, and further, for the reason that it is my opinion that the organic matters contained in the Chicago sewage conveyed into the Illinois River by the Illinois and Michigan Canal and the Chicago main drainage channel, so far as the sanitary chemical analysis can determine, are destroyed completely or converted into mineral matters and vegetable matter, which, as contained in such water, are practically innocuous." (5643.)

Professor John H. Long testified as follows:

"Because of the addition of a large volume of Lake Michigan water to the Canal water flowing down the Illinois, and because, further, the increase in the amount of pure water is very much in excess of the increase in the amount of sewage carried at the same time, the resultant effect is produced that the mouth of the Illinois River to-day is in a far better sanitary condition than obtained before the Drainage Canal opened. Taking into consideration all the conditions which have been supposed, and especially the condition of the increased pollution, I am still of the opinion that the sanitary condition of the water of the Illinois River at its mouth has been improved instead of injured by the increased flow through the Drainage Canal. And beyond all possible question the sanitary condition of the Illinois River at its mouth is far superior to the Missouri River at its mouth and not greatly different from the condition of the Mississippi River at a point where the Illinois and Mississippi

Rivers united. As I have stated in my previous testimony, I believe the effect of the Chicago sewage is completely lost before the mouth of the Illinois River is reached, and therefore cannot be a factor in determining any pollution in the Mississippi or Missouri Rivers." (4254-6.)

Professor W. P. Mason testified as follows:

"My opinion is that typhoid fever bacilli coming from the sewers of Chicago would not be a danger and a menace to the inhabitants of St. Louis using the water of the Mississippi for drinking and domestic purposes." (6921.)

"Q. Professor Sedgwick, in answer to the question: 'Assuming that the germs of typhoid fever coming from the sewers of Chicago and passing by way of the Drainage Canal to Lake Peoria be in large numbers deposited in the bed of Lake Peoria for the period of a month, say, do you consider that typhoid germs would be entirely destroyed at the end of that time in that deposit?' answered 'No, sir.' What do you say as to the assumption that typhoid germs could pass from the sewers of Chicago, by way of the Drainage Canal to Lake Peoria, and be deposited there in the bed of Lake Peoria for the period of a month, and as to whether or not typhoid germs coming from the Drainage Canal, under conditions as they exist to-day, would live for the period of a month and not be destroyed before the end of that period?

"A. I do not believe that they would live for that period of time under those conditions, and I base my opinion very largely upon experiments similar to what I described this morning, the tank experiment which was made by the Massachusetts Board of Health, and, moreover, *it is to be remembered that the burden of proof should be on the part of those who make the statement that the germs so live.*" (6946.)

"Assuming that the only pollution of the river was that contributed to it by the Chicago Drainage Canal, and having in mind a large amount of typhoid fever existing in said district, I think that the water of the river as it enters the Mississippi River is not liable to produce typhoid fever among those using it." (6948.)

"I have no knowledge of the presence of infected Chicago sewage in the Illinois River at Grafton and I believe that the use of the water of the Mississippi at the Chain of Rocks, because of the admixture of water from the Illinois River, would not be a menace to the health of the inhabitants of St. Louis.

"I do not consider that the waters of the Illinois River, under the conditions obtaining, commingled with the waters of the Mississippi River, are a menace to the inhabitants of the State of Missouri living upon the Mississippi River and using the waters of the Mississippi River for drinking purposes at points on the Missouri shore." (6949.)

"I do not believe that dangerous infection and dangerous pollution might under existing conditions find their way into the water supply of the City of St. Louis.

"I believe that typhoid germs derived from the Sanitary District of Chicago are not liable to find their way into the water supply of the City of St. Louis through the intake tower at the Chain of Rocks and become a danger and a menace to the inhabitants of the City of St. Louis." (6950.)

"Q. Professor Sedgwick, in answer to the question just propounded to you, stated: 'I believe they are liable to find their way to the intake,' and when asked why, answered, 'For the reason that typhoid fever having been frequently very abundant in the City of Chicago, I must start with the assumption that a very large number of typhoid germs find their way into the sewage of the city, pass through the sewers and on into the Drainage Canal, and, subject to local conditions, may, in diminishing numbers, pass out of the Illinois River, mingle with the waters of the Mississippi River, pass over to the other side and find their way into the intake at the Chain of Rocks.' Now, Professor, I want to ask you, do you know of any evidence, based upon any analysis, experiments or otherwise, that justifies the assumption that typhoid fever germs will pass through the sewers and on into the Drainage Canal and subject to local conditions may, in diminishing numbers, pass out of the Illinois River, mingle with the waters of the Mississippi River, and pass

over to the other side and find their way into the intake at the Chain of Rocks at the St. Louis water supply? (6950.)

"A. I do not know of any analysis or experiments that justify such assumption, but on the contrary I am of the opinion that the charts which I have offered in evidence show that there is no connection between typhoid fever in the City of St. Louis and of the City of Chicago, and were it liable that typhoid germs should pass into the water at the intake, I should expect that the curves of typhoid fever in St. Louis and in Chicago would show parallelism whereas they show quite the reverse." (p. 6951.)

"I do not consider that the Illinois River water since the opening of the Drainage Canal, has rendered less safe and wholesome for drinking purposes on the part of the inhabitants of the State of Missouri, the waters of the Mississippi River below the mouth of the Illinois River." (p. 6952.)

"Taking into consideration all the knowledge that I possess in regard to the bacterial, chemical and physical conditions of the waters of the Illinois River, and its tributaries and of the river itself and of the different towns sewering into the Illinois River and its tributaries, the population upon the watershed of the Illinois River, both rural and urban, the discharge of the river under all conditions and during all seasons, it is my opinion that flowing the sewage from Chicago through the Drainage Canal into the Desplaines and Illinois River has no material effect upon the health of the inhabitants of the State of Missouri using the waters of the Mississippi River for drinking and domestic purposes." (p. 6954.)

Professor Leonard P. Kinnicutt testified as follows:

"Knowing the character of the Illinois River and bearing in mind the amount of sedimentation, the amount of dilution and the amount of purification that occurs between Chicago and Grafton, and especially bearing in mind the time element, I do believe that the time interval would render the Mississippi River water at all times free from liability of producing water-

borne diseases from pathogenic bacteria entering the Illinois River by way of the Drainage Canal." (p. 7453-4.)

"From all the knowledge that I possess as a sanitary expert, I do not believe that the water of the Ilinois River at Grafton is infected from the sewage of Chicago, meaning by infection typhoid bacilli which came into the Illinois River from the Chicago sewage, and this being my opinion I do not consider that the water from the Illinois River mixed with the water of the Mississippi River at Grafton and subsequently mixed with the waters of the Missouri River at its mouth, thus commingling with the waters of the Mississippi and Missouri Rivers, is a menace to the health of the inhabitants living upon the Mississippi River, using the Mississippi River water for drinking purposes at points on the Missouri shore." (p. 7454.)

"It being my opinion that typhoid fever bacilli from Chicago entering the Illinois River do not survive the journey from Chicago to Grafton, and assuming that there were no typhoid fever pollutions of the waters upon the watershed of the Mississippi River, or its tributaries, above the intake of the St. Louis waterworks, except that which came from Chicago, my opinion is, for the reasons stated above, that typhoid fever germs from said district are not liable to find their way into the water supply of the city of St. Louis through the intake tower at the Chain of Rocks." (7454-5.)

"From all the data that I have studied, and from all the knowledge that I have been able to obtain regarding the Illinois River, I find not the slightest evidence that the Illinois River, containing the mixed sewage and canal water from the Chicago Drainage District since the opening of the Drainage Canal renders the waters of the Mississippi River below the mouth of the Illinois River less safe and wholesome than it was before the opening of the canal, for drinking purposes, on the part of the inhabitants of Missouri." (7456-6.)

"From various experiments that have been made, it has been shown that the vitality of the typhoid bacilli is greater in pure water than in water polluted by sewage, and basing my

opinion on these facts, it is my opinion that the sewage from Chicago does not favor the longevity or growth of germs from Peoria or anywhere else emptying their sewage into the Illinois River." (p. 7456.)

"From my knowledge of the Illinois River, flowing as it does at highwater over a very large amount of territory, and the fact that the river is studded with lakes, nearly all the way from upper Peoria Lake to its mouth, I do not believe that even at the different stages of water of the Illinois River, the sewage from the City of Chicago, passing through the Drainage Canal into the Illinois, at different seasons of the year, would be a danger or a menace to the inhabitants of Missouri and the citizens of the City of St. Louis using the water of the Mississippi River at the intake tower, at the Chain of Rocks." (7459.)

"It is my opinion as a sanitary expert, and with a knowledge of conditions that obtain in and along the Illinois River, and from the evidence that has been submitted in this case, that such infected matter or pathogenic germs which come into the Drainage Canal from Chicago, do not reach as far down the Illinois River as the City of Grafton." (7460.)

"If they would not reach as far down the Illinois River as the City of Grafton, it is impossible that any of these substances in a dangerous state would reach the intake tower of the St. Louis waterworks at the Chain of Rocks."

"For the reasons which I have already stated, which are based upon all the knowledge which I have been able to obtain, regarding the Illinois River, I do not consider that the sewage of Chicago, entering the Drainage Canal, and the Illinois River, which in turn empties into the Mississippi River, a menace and a danger to the inhabitants of the State of Missouri or to the citizens of the City of St. Louis, taking their water supply from the Mississippi River." (p. 7460.)

"In my opinion, the only effect the pollution and contamination from the sewers of Chicago, entering into the Chicago River, thence into the Drainage Canal, that could be noticed at the Chain of Rocks on the Mississippi River, is a higher chlorine and nitrogen contents of the river."

"From a study of the analytical data, which has been submitted in evidence in this case, it is my opinion that all this analytical data shows that this organic matter of the sewage from Chicago has been decomposed before it reaches Grafton. Consequently, none of the organic matter from the sewage of Chicago finds its way into the intake tower of the St. Louis waterworks at the Chain of Rocks." (pp. 7461-2.)

"It is my opinion all the examinations that I have studied, as well as my own tables and charts show, that the waters of the Illinois River at Grafton are in a purer state since the opening of the Drainage Canal."

"The only effect in my opinion that the sewage discharged through the Drainage Canal has upon the Missouri or Mississippi River waters at the Chain of Rocks is in the increase in the amount of chlorine and also in the quantity of nitrogen contents, neither of which elements as far as known, has any effect upon the human system."

"The sewage of Chicago as sewage in my opinion never reaches the Mississippi River at the Chain of Rocks, at the intake tower." (p. 7463.)

Mr. John W. Hill testified as follows:

"The information which I have with reference to the Illinois River and the quantity and quality of the stream flow, its physical characteristics and the technical data obtained from an examination of the water samples does not warrant the belief that infected matter from Chicago would be found in the Illinois River as far south as Grafton."

"Taking into consideration all the facts and considering the three drainage basins, namely, the Illinois, the Mississippi and Missouri, upon each of which are found many cities, some of considerable population, like Peoria and Chicago on the Illinois Drainage basin, and Dubuque, Davenport, Burlington, Des Moines, Rock Island, Moline and Quincy on the Mississippi River basin and Kansas City, Topeka, St. Joe and Omaha on the Missouri basin, in all of which cities it is probable that typhoid fever prevails during the usual season of typhoid fever and in

some of these cities prevails at all times, and especially keeping in mind the larger cities close to St. Louis, it would be wholly impossible in my opinion to say from what city the typhoid fever organism found in the Mississippi River, opposite St. Louis, would come. If it were true that any one of the cities on either of the watersheds not too far removed from St. Louis had typhoid fever while the other cities on the other watersheds did not have it, after allowing for the usual time between the infection of the stream and the discovery of the organism at St. Louis, it might be charged to that city, whichever one it might be, but statistics show that in all the larger cities of the country typhoid fever always prevails, and where the drainage of three watersheds combined as in the Mississippi River in front of St. Louis, I know of no process whereby the typhoid fever organism there found could be assigned to the probable locality from which it came." (pp. 7550-1.)

"I have no data that would bear out such an assumption that a typhoid fever germ could lie in the sediment of the Drainage Canal or upon the bottom of the Illinois River for a period of from one to three years. And I do not know of any experiments ever made that would furnish reasonably exact information upon the matter similar to that embraced in the question."

"It is my opinion that typhoid bacilli deposited on the bottom of the Illinois River could not remain there for a period of upwards of five years and then be stirred up by the action of the waves, wind, steam boats, or by any other means and continue its journey down to St. Louis and be a cause of danger to the inhabitants of the State of Missouri and the citizens of St. Louis using the water of the Mississippi River for drinking and domestic purposes. I do not think that a typhoid organism would live for five years in the sediment of a river." (p. 7551.)

"It is my opinion, upon the technical data before me, the sanitary condition of the water of the Illinois River at Grafton since the opening of the Drainage Canal has been improved."

"Assuming that the opinion which I have given as to the

quality of the Illinois River at Grafton is no worse after the opening of the Drainage Canal than it was (as shown by the technical investigations) before the opening of the Drainage Canal, it would have no marked influence on the quality of the combined waters of the Mississippi River passing the Chain of Rocks." (p. 7552.)

"Assuming that the bacteriological and chemical investigations applied to a water supply are acceptable as showing whether it is or is not fit for domestic uses * * * I wish to be understood simply as stating that there is no evidence before me showing such change having occurred in the quality of the water as to render it less desirable for potable purposes and more deleterious to health than existed prior to the opening of the Drainage Canal." (p. 7554.)

Professor Theobald Smith testified as follows:

"It seems to me that if virulent typhoid bacilli should actually pass from Chicago to the mouth of the Illinois River that it would be according to conditions and laws that we know nothing about, but that basing ourselves upon the close relationship of the colon to the typhoid bacillus and to this entire group of disease germs, we are at present justified in saying that the virulent typhoid fever bacilli would be very largely destroyed at that point."

"It would seem to me that the disappearance of the colon bacilli indicates that excluding a large amount of sewage which enters below Chicago the typhoid bacillus would probably be entirely eliminated during that long course from Chicago to the mouth of the Illinois River of three hundred and fifty odd miles." (p. 7300.)

"It seems to me that considering the enormous destruction of the colon bacillus from Chicago down to Averyville, the very great influx of sewage at Peoria, that the presumptive evidence is very strong that the typhoid bacillus from Chicago would not reach St. Louis because it is highly probable that the colon bacilli at the mouth of the Illinois River are probably those that

have been introduced further down the stream, say at Peoria and other sewage-discharging places." (p. 7301.)

"Q. Knowing the typhoid condition in the City of St. Louis and assuming that the same was due to water supply, where would you look for the source of infection, to points as far away as the City of Chicago, or to points nearer than the City of Chicago?

"A. I should first look to the points nearer by all means, and if those could be eliminated then I think I should look to the City of Chicago.

"Q. From a consideration of the typhoid fever upon the watershed tributary to St. Louis, would it be reasonable to eliminate the points near at hand in looking for the source for cause of infection in St. Louis, assuming that it came from a water supply?

"A. I think it would be highly important to locate the nearest sources first because of the vulnerability of typhoid bacillus in water. The further the area of infection, the less the danger of a typhoid bacilli reaching the water supply. A few bacilli discharged into a stream near by would be much more dangerous than a large number discharged at a much greater distance." (p. 7304.)

Professor Edwin O. Jordan testified as follows:

"I not only know of no evidence that indicates that accumulations of typhoid fever bacteria take place in lakes or slack water basins of rivers and remain there in storage, but on the contrary it is my opinion that the evidence available on this point shows distinctly that no such accumulations take place. It is my belief, as already stated in my testimony, that typhoid germs introduced into sediment under these conditions speedily perish and would not survive so long in a virulent state that they could at some future time be flushed out from such slack water basins."

"It is possible that where deposits of sewage matter are fresh and recent, as they are, for example, in the bed of the

Chicago River, that the sudden flushing out of such a stream might lead to an outbreak of typhoid fever within two or three days' distance from such deposits. But where sewage matter has been deposited on the bed of a stream and allowed to remain there for a period of several weeks, without receiving any addition of fresh material, I know of no instance where an epidemic of typhoid fever has been traced beyond all reasonable doubt to the removal or flushing out of deposits of such sewage matter." (p. 6318.)

"It is my opinion, assuming that the only pollution of the Illinois River was that contributed by the Chicago Sanitary District, and considering the presence of dilution of sedimentation and particularly of the time interval occurring between Chicago and Grafton, that these would be factors of sufficient power to render the water of the Illinois River as it empties in the Mississippi River free from the liability of introducing typhoid fever or any other water-borne disease among the drinking such water." (p. 6319.)

"From all the knowledge that I have, I have formed the opinion that the water of the Illinois River at Grafton does not contain infectious elements derived from the sewage of Chicago, and that consequently such water reaching the Mississippi River and becoming mixed with that water is not a menace to the health of the inhabitants of the State of Missouri, on the Missouri shore of the Mississippi River or to the citizens of St. Louis." (p. 6320.)

"I know of no evidence that indicates, directly or indirectly, that the waters of the Illinois River at Grafton are infected from the sewers of Chicago, and in view of the large amount of pollution of the Illinois River, that takes place at points less remote from its mouth than Chicago, it is my opinion that convincing evidence of such infection coming from Chicago would be very difficult, if not impossible, to secure." (p. 6320.)

"I do not believe that infectious or dangerous matter passing into the sewers of Chicago finds its way, under existing conditions, into the water supply of the City of St. Louis for reasons which I have set forth previously in great detail."

"Assuming that there was no typhoid fever pollution of the waters of the watershed of the Mississippi River or its tributaries above the intake of the St. Louis waterworks other than that derived from the Sanitary District of Chicago, I certainly do not believe that typhoid fever germs from said district would be liable to find their way under existing conditions into the water supply of St. Louis." (p. 6321.)

"Q. Professor Sedgwick, in answer to the foregoing question, stated: 'I believe that they are liable to find their way into the intake,' and when asked why, answered, 'For the reason that typhoid fever having been frequently abundant in the City of Chicago, I must start with the assumption that a very large number of typhoid germs find their way into the sewage of the city, pass through the sewers and on into the Drainage Canal and subject to local conditions, may, in diminishing numbers, pass out of the Illinois River, mingle with the waters of the Mississippi, pass over to the other side and find their way into the intake at the Chain of Rocks.' I want to ask you, Professor, do you know of any evidence based upon any analysis, experiments or otherwise, that justify the assumption that typhoid fever germs will pass from Chicago, out of the Illinois River, into the Mississippi River, thence to the Chain of Rocks and the intake tower of St. Louis?

"A. I have myself made a number of analyses, experiments, and observations upon the waters of the Drainage Canal, the Illinois and Mississippi Rivers and have examined with some care the reports of analyses, experiments and observations made by others, and I have been unable to discover any evidence that justifies the assumption that typhoid fever germs can or do pass from Chicago out of the Illinois River into the Mississippi River, thence to the Chain of Rocks and the intake tower of St. Louis." (pp. 6321-2.)

"Q. I want to ask you this question which was asked of Professor Sedgwick, page 3470 of the transcript which I have: 'Now, Professor, considering your personal knowledge as an expert of typhoid fever conditions in the Sanitary District of

Chicago, under existing conditions in said district as to sewers and the outfalls there are and the amount of sewage and all the existing conditions of the Desplaines, Illinois, Mississippi and Missouri Rivers, and all conditions existing upon the watersheds of said streams and of the tributaries thereof, and all existing conditions as to the water supply of the City of St. Louis and the general sanitary conditions existing in the City of St. Louis, would you or not beyond a reasonable doubt attribute the principal portion of the increase of typhoid fever in St. Louis since the opening of the Drainage Canal, to the infected sewage of the Sanitary District of Chicago?'

"A. I certainly should not.

"Q. Why?

"A. Assuming that there had actually been a marked increase in typhoid fever in St. Louis since the opening of the Drainage Canal, which appears to me to be contrary to the fact, it would, in my opinion, be more reasonable and significant to attribute such an increase in typhoid fever to other causes, such, for example, as an infection of the water supply nearer the water intake, to infection of the milk supply or to some other factor rather than to infected sewage coming from the Sanitary District of Chicago." (p. 6323.)

"It is my opinion and judgment that the chemical, bacteriological and epidemiological evidence is altogether convincing that the water of the Illinois River at its mouth is no more unsafe and unwholesome now than it was before the opening of the canal, and that consequently the water of the Illinois River since the opening of the canal has not rendered less safe and wholesome the waters of the Mississippi River below the mouth of the Illinois River."

"It is my best judgment that the inhabitants of Missouri, using the Mississippi River water below the mouth of the Illinois for drinking purposes are not, under existing conditions liable to contract typhoid fever by reason of sewage from the Chicago Drainage Canal infecting the waters of the Illinois River." (p. 6324.)

"I do not consider that any pollution or infection with sewage from Chicago Sanitary District, since the opening of the Drainage Canal, has rendered less safe the Illinois River water at its mouth or in consequence the water supply of the City of St. Louis as drawn at the intake tower at the Chain of Rocks."

"Q. This question, on page 3497 of my record, was asked of Professor Sedgwick, which I desire to ask of you: 'Assuming that the population of the Sanitary District of Chicago covers about 3,000,000 people and that the flow through the Drainage Canal reaches 600,000 cubic feet a minute, what in your opinion would be the effect upon the water of the Illinois River as compared with that water at its mouth as found during the past three years?'

"A. I do not believe that the sanitary quality of the Illinois River water at its mouth would be affected by a change in conditions such as that indicated in the question." (p. 6326.)

"From a long and searching examination of all data, chemical, bacteriological and epidemiological, from every source that I have been able to secure I am convinced that the citizens of the City of St. Louis and the inhabitants of the State of Missouri are not menaced by or endangered by infectious materials passing into the sewers of Chicago and thence into the Drainage Canal."

"Comparing the Missouri River near its mouth with the Illinois River above Grafton, and the Mississippi River above Grafton, I have no hesitation in saying that I regard the waters of the Mississippi and Illinois, at the point indicated, less dangerous and less unwholesome than the waters of the Missouri River. Between the Illinois and the Mississippi Rivers, at the point indicated, there is, in my opinion, not much to choose from a sanitary point of view." (p. 6332.)

"Such an admixture as occurred of the Illinois River water with the Missouri River water would tend to improve the quality of the water since the number of colon bacilli in the waters of the Missouri River are distinctly greater than those in the waters of the Illinois, and this condition, in my opinion

indicates that the Missouri River water, which is more highly charged with these objectionable bacteria, is more likely to be the vehicle of typhoid fever bacilli than the water of the Illinois which does not contain so many bacteria of this type."

"All the analytical data that I have obtained myself and all that I have seen which has been obtained by other investigators indicate both from the chemical changes that take place and from the diminution in the number of ordinary sewage bacteria and especially in the diminution of the number of bacillus coli communis that under existing conditions, infectious materials introduced into the sewers of Chicago cannot and do not pass down the Illinois River as far as Grafton." (p. 6333.)

"Q. What is your opinion as to whether a typhoid bacillus deposited on the bottom of the Illinois River could remain there for a period upwards of five years and then be stirred up by the action of the waves, winds, steam-boats or other means, could continue its journey down to St. Louis in a virile state and be a cause of danger to the inhabitants of the State of Missouri using the water of the Mississippi River and to the inhabitants of the City of St. Louis using the water of the Mississippi River for drinking purposes?

"A. The hypothetical case proposed in your question of a typhoid bacillus living as long as five years in the sediment of the Illinois River and retaining its virulence during that period is, so far as I am aware, wholly without basis in observed fact and finds no support in the deductions that can be drawn from my own observations or from the observations of others upon the conditions prevailing in the Illinois River or elsewhere. (pp. 6335-6.)

"Q. What is your opinion as an expert chemist and bacteriologist, as to whether the pollution and contamination from the sewers of Chicago, emptying into the Chicago River and thence into the Drainage Canal, continues to be manifest and persistent as far down the Illinois River as Grafton and at the Chain of Rocks on the Mississippi River?

"A. The pollution that has occurred at Chicago is manifest

at the mouth of the Illinois River chiefly in the increased amount of chlorine present in the water of the Illinois River at that point. The introduction of a large amount of nitrogenous organic matter is also betrayed by the large amounts of various compounds containing nitrogen present in the water of the Illinois River at its mouth, but so far as the original polluting matters and pathogenic bacteria introduced into the Chicago Drainage Canal are concerned, I can find no grounds for adopting the opinion that these substances and these bacteria persist in their original condition as far down the river as Grafton. (p. 6336.)

"Q. If the typhoid condition in St. Louis since 1900 cannot be attributed to the sewage from Chicago beyond a reasonable doubt, will you please state what cause in your opinion it should be attributed to and give your reasons for such an opinion?

"A. Assuming that the amount of typhoid fever occurring in St. Louis during the period mentioned is in excess of what would naturally exist in a city provided with a fairly pure and satisfactory municipal water supply, in my opinion the most rational and scientific explanation of such excess would lie in the infection of the Illinois, Mississippi and Missouri Rivers above the intake tower of the St. Louis waterworks by communities, rural and urban, within five or six days flow from the intake tower. Since in my opinion, the major part of the water supplied to St. Louis during this period was derived from the Missouri River and inasmuch as it is my opinion the Missouri River is more seriously infected than either of the other rivers mentioned, it is my judgment that the infection of the Missouri River has been the main factor in causing such excess of typhoid fever in St. Louis as occurred during the period under consideration."

"It is my opinion, assigning due consideration to all the facts mentioned, that the discharge of the sewage of Chicago into the Drainage Canal has had no injurious or detrimental effect upon the health of the inhabitants of St. Louis or the State of Missouri. (p. 6342.)

"Summing up all the experience I have gained in my studies of the Illinois and Mississippi and Missouri Rivers and their tributaries and all the information that I have gained from all sources, it is my firm opinion that no relation near or remote has been traced between the typhoid conditions in St. Louis since January 17, 1900, and the opening of the Drainage Canal on that date; and it is further my opinion that no such relation exists, and that the opening of the Drainage Canal was an event entirely unconnected and unrelated with any typhoidal conditions prevailing in St. Louis at that time, and has remained up to the present time, unrelated and unconnected with the typhoid fever mortality in the City of St. Louis." (p. 6343.)

Cholera.

"The statements that I have already made regarding my opinion as to the life of the typhoid bacillus in the waters of the Illinois River, under existing conditions, apply with even more force to the possible longevity of the cholera spirillum. The danger in my opinion would not be imminent, impending or immediate to the people of Missouri below Grafton who use the waters of the river for drinking purposes, but would on the contrary be imaginary, hypothetical and non-existent." (p. 6327.)

A careful consideration of the testimony, as well as of the qualifications and scientific attainments of the men whose testimony is quoted, shows the careful preparation, deep scientific investigation and research made by these eminent investigators previous to having expressed their opinions.

Expert testimony is of value only when backed by personal scientific investigations, deep research and study and accurate and ascertained facts. Theories and speculation are not scientific demonstration. In the language of Mr. Whipple, one of the witnesses for complainant, "a judgment cannot be scientific when the facts upon which that judgment is predicated are incapable of scientific demonstration." (2180.)

The witnesses whose testimony has hereinbefore been quoted

drew no conclusions based upon assumptions such as were made in regard to the Detroit epidemic, the Washington epidemic, the Covington (Kentucky) epidemic or the Zurich or Lake Geneva incident in Switzerland; for as has been demonstrated and proven in the evidence, these so-called epidemics offered no criteria for a basis from which to draw conclusions as to the longevity of the typhoid germ in sediment, in flowing water or otherwise. But the testimony hereinbefore quoted based upon chemical and bacterial analyses, together with an experiment upon the longevity of the typhoid germ under natural conditions, the scope and extent of which has never been attempted by any investigators, demonstrate scientifically and conclusively that a typhoid germ leaving the sewers of Chicago by way of the Chicago River and the Drainage Canal, could not survive the journey down the Desplaines and Illinois Rivers to the intake tower at St. Louis in a virulent condition, but would perish long before the mouth of the Illinois River at Grafton was reached.

This opinion, backed by scientific investigation and scientific knowledge, is held by the eminent investigators and scientists whose testimony is hereinbefore quoted, and a careful consideration of their entire testimony, together with the able cross-examination of the distinguished counsel representing complainant, failed to show that those opinions are not sustained by scientific research throughout the world, as well as by scientific knowledge and experimental demonstration introduced into the testimony in this case. Considering, as they did, the typhoid conditions in the City of St. Louis prior and subsequent to the opening of the Drainage Canal; considering that each one of these scientific witnesses had a personal knowledge of the topographical conditions of the water course from the mouth of the Chicago River to the Eads Bridge at St. Louis, acquired by a personal visit down the river, as the evidence in this case will disclose; taking into consideration the opportunities that these witnesses had for becoming acquainted with conditions, physical, chemical and bacteriological; and

more important still, taking into consideration their entire testimony given in this case as well as that hereinabove quoted, the evidence shows from a scientific standpoint a harmony, a unanimity and an agreement among these eminent men which demonstrates and proves as conclusively as any scientific evidence can prove that typhoid germs leaving the sewers of Chicago in a virulent condition, able to cause typhoid fever among the inhabitants of Missouri, will not survive the journey to St. Louis, and consequently cannot become a danger and a menace to the inhabitants of the State of Missouri, taking their water supply from the waters of the Mississippi River.

That being the case, the opening of the Drainage Canal was not and is not a danger and a menace, present or impending, to the inhabitants of the State of Missouri taking their water supply from the Mississippi River, for the reason that a typhoid germ leaving the City of Chicago by way of the Drainage Canal would have perished long before Grafton, at the mouth of the Illinois River is reached.

XI.

THE NECESSITY OF PURIFYING, BY FILTRATION OR OTHER MEANS, THE WATER SUPPLY OF THE CITY OF ST. LOUIS AS THE SAME IS DERIVED FROM THE MISSISSIPPI RIVER, EXISTED AS FAR BACK AS 1866, AND WAS SO RECOGNIZED BY THE AUTHORITIES IN ST. LOUIS, AND HAS CONTINUED TO BE SO RECOGNIZED UP TO THE PRESENT TIME.

In a resolution passed by the Board of Water Commissioners of St. Louis on December 11th, 1865, it was "Resolved, That James P. Kirkwood, Esq., our chief engineer, be requested to proceed at once to Europe and there inform himself in regard to the best processes in use for the clarifying of river waters used for the supply of cities, whether by deposition alone or by deposition and filtration combined, making such an examination in each instance as will enable him to report to this board the general dimensions and special characteristics of the specific works visited by him, so that this board may be able to appreciate how far the same mechanically and the same or similar combinations of materials are likely to be adaptable to the purifying of the Mississippi water at St. Louis." (See Vol. 7, p. 6866.)

Mr. John W. Hill, of Philadelphia, testified as follows:

"Q. How long have you been acquainted with the water supply of the City of St. Louis?

"A. By means of the annual reports of the Water Commissioners for twenty years, and taking into consideration the report of Mr. J. P. Kirkwood, made in 1866 or 1867, which was the basis for the general reorganization of the waterworks of St. Louis, for a period of thirty-six or thirty-seven years, because Kirkwood's work was one of the early works that I studied in connection with public water supplies.

"Q. Who was Mr. Kirkwood, to whom you refer?

"A. Mr. Kirkwood was one of the most eminent hydraulic or waterworks engineers in the United States, and in 1865 or

1866 was employed by the City of St. Louis to develop plans for the general improvement of the water supply.

"Q. Did you know Mr. Kirkwood?

"A. I met him once some twenty years or more ago in New York.

"Q. Is that the Mr. Kirkwood that visited Europe and made a report on filtration to the City of St. Louis?

"A. The same.

"Q. And that report has been published?

"A. Yes, sir. He made what was the earliest and for many years considered as the most elaborate report on the filtration works of Europe, that was printed in the English language." (7533.)

It will be observed that as far back as 1866 the City of St. Louis recognized the necessity of having its water purified by filtration.

In recognition of this fact the testimony of Dr. Ravold and witnesses called by the complainant in this case in regard to the potability of the Illinois, Mississippi and Missouri Rivers, shows that the waters of those three rivers were not potable before the opening of the Drainage Canal, as evidenced by the following testimony given by Dr. Ravold:

"Q. Then isn't it true of all the periods to which you have referred as the first, second and third periods of our investigations here?

"A. Yes, sir.

"Q. So that you are not surprised to find, then, in all these waters a large number of bacteria at different times?

"A. No, sir.

"Q. Would you have been greatly surprised if you had not found any?

"A. If I had not found any at Lockport, I don't know what would have happened to me, but I would have been terribly disappointed.

"Q. Are the rivers generally in this country and in Europe in such a condition as to render them unfit for water supply for cities without some kind of sedimentation or filtration?

"A. Yes, sir.

"Q. That is, they are unfit?

"A. Yes, sir; as a rule.

"Q. That applies to all the rivers to which you have referred in your examination here?

"A. Yes, sir.

"Q. As a bacteriologist, then, you would not recommend supplying cities with water taken from the running streams of this country without some system of sedimentation or filtration being adopted for the purpose of removing the bacteria?

"A. No, sir, I would not.

"Q. That opinion applies to all the rivers of which you have spoken in this examination, does it not?

"A. Yes, sir; because all these rivers have sewage discharged into them." (See Vol. I, pp. 895, 896.)

This testimony shows that Dr. Ravold, who was the city bacteriologist of the City of St. Louis, recognized that the waters of the Missouri and Mississippi, exclusive of the waters of the Illinois, were not potable waters, and should not be used, for drinking and domestic purposes, without sedimentation or filtration.

And in view of the evidence in this case already referred to in this brief, which establishes the comparative pollution of the Missouri, Mississippi and Illinois Rivers, together with the report on filtration submitted to the authorities of the City of St. Louis by Mr. Allen Hazen and Mr. George W. Fuller (witnesses who have testified in this case, recommending filtration for that water supply) there can be no question that if the bear-trap dam had never been lowered, and the Drainage Canal never opened, the necessity for filtering the water supply of the City of St. Louis, or resorting to some additional mechanical means of purifying its water different from that which obtained in 1900, would have existed; and the evidence in this case fails completely to show that prior to 1900 the water supply of St. Louis, as treated by the settling basins, was a good and safe water supply to be used by the citizens of St. Louis for drinking and domestic purposes.

The witnesses in this case who have testified that the Missouri River was a potable stream were Professor Teichmann, whose testimony on that point has already been quoted, and Professor Keiser, who stated that, "from a sanitary standpoint, the water from the Mississippi River above the mouth of the Illinois is very similar to the water of the Missouri River, and were it not for the inflow of the waters of the Illinois River, the Mississippi on both sides of the river at the Chain of Rocks would be of equal character. *It would be good drinking water on both sides.*" (1042.)

In addition to the testimony quoted from Professor Teichmann, that the waters of the Missouri and Mississippi Rivers were potable, he also testified on pages 1446, 1447, as to the conditions prior to 1900, as follows:

"Q. During the five years previous to 1900, was the water supply of St. Louis as found in the hydrants, good, potable water?

"A. No, sir.

"Q. Did it require boiling?

"A. Yes, sir.

"Q. Did it require filtration?

"A. It should have been filtered, yes, sir. (1446.)

* * * * * * * * *

"Q. For how long a period of time has the Health Department of St. Louis advised the citizens not to drink the water of St. Louis?

"A. Oh, that has been done since 1893, since I assumed charge of the office of City Chemist, and analyzed the water.

"Q. What was the character of the pollution of the water in St. Louis prior to the opening of the Sanitary District?

"A. The water as proved to be prior to the opening of the Drainage Canal was polluted.

"Q. With what?

"A. The analytical results showed pollution in a measure from sewage, and in a measure of vegetable origin.

"Q. Where did the sewage come from that got into the water of St. Louis?

"A. In my opinion, as a result of my investigation in 1899, I found that the Missouri River and the Mississippi River above the mouth of the Illinois, were of much better sanitary quality than the Illinois River at the mouth of the Illinois, and I found at that time that the Illinois River polluted the Mississippi River after meeting the Mississippi River, and that this pollution extended along the line or along the route of the Mississippi River as it came down and passed the intake, or at times when the Missouri River was low it would go into the intake.

"Q. At that time was the Missouri River water potable water?

"A. Yes, sir." (1447.)

This testimony of Professor Teichmann, indeed, is very interesting when taken in connection with his other testimony given in this case and heretofore quoted; but, more interesting still is that testimony introduced in evidence from the Board of Health Reports of St. Louis as contained in the 17th Annual Report of the Health Commission of St. Louis for the years 1893 and 1894, when the chemical examinations made by Dr. Teichmann of the waters of the Illinois River were submitted on October 16th of that year, with the samples collected from the Mississippi and Illinois Rivers at the intake in conformity with requests made upon him by the Board of Health of the City of St. Louis.

The results of these tests were charted and submitted to the Mayor of the city, and a letter transmitted by the Mayor to the Health Commission, based upon this analytical data, is of great interest taken in connection with Dr. Teichmann's testimony hereinabove quoted. The Mayor's letter is in part as follows:

"I have examined these charts and reports as carefully as my want of technical knowledge will permit. The result of the work is undoubtedly presented in a very graphic manner; indeed, it seems to me that a technical knowledge is hardly necessary to understand the results as shown by the reports and

charts before me, assuming that the work of the City Chemist so far as it went was thorough and reliable. I have no reason to doubt that the City Chemist, Teichmann's, work can be depended on as representing the true conditions. It is my understanding that this investigation was the result of a suspicion that our water supply was being contaminated by Chicago sewage coming from the Illinois River.

"Briefly, then, I find from the charts before me conditions as follows:

"Substances supposed to contaminate drinking water in dangerous quantity in the Illinois River, also spots in the Mississippi River between the mouth of the Illinois and the Chain of Rocks and in the mouth of the Missouri River. I find, however, that at Grafton, about one mile and a half below the mouth of the Illinois, the water is purer than at any other point in the river between Grafton and the Chain of Rocks. That is to say, nothing of the objectionable substances seem to exist in dangerous quantities one mile and a half below the supposed source of contamination, while the pollution increases and diminishes below that point at regular intervals. This, it seems to me, tends to disprove the theory that the contamination (if there be any) at the Chain of Rocks comes from the Illinois River, and goes to show that the offensive substances found in spots along the river between the mouth of the Illinois and the Chain of Rocks are due to local causes. The comparative purity of the water at Grafton seems to be inconsistent with the theory that the water below that point is contaminated from the water from the Illinois River. The conditions existing at the mouth of the Missouri River, as shown by the chart, suggest *that* as a much more probable source of the pollution than the Illinois River." (6674, 6678.)

When the foregoing letter of the Mayor is considered in connection with the statement of Dr. Teichmann that since 1893 it was necessary to boil the water taken from the river at St. Louis because of its sewage pollution, and compared with his testimony attributing the pollution of the water supply to the

Illinois River, it merely demonstrates, as is often demonstrated in this case, that theories do not walk hand in hand with facts.

Professor Sedgwick, who testified in this case on the part of complainant, does not differ materially from the views expressed by Professor Teichmann and Professor Keiser as to the conditions of the water supply of St. Louis prior to 1900. In his testimony on page 2202 he states:

"I have made a rather careful study of the typhoid fever statistics of the City of St. Louis, and with this general result: During a period of fifteen years prior to January 1st, 1900, the typhoid fever death rate in St. Louis had not in general been above that of some cities provided with water supplies considered pure, and of good repute."

The only inference that can be drawn from this statement of Professor Sedgwick is that the water supply of St. Louis before January 1st, 1900, was pure and of good repute, which shows that he had entertained the same views at the time he testified as did Professors Teichmann and Keiser; but, subsequently in his testimony we find him giving expressions to somewhat different conclusions.

Professor Sedgwick stated that, the combined waters of the Illinois, Mississippi and Missouri Rivers at St. Louis, with the Sanitary District eliminated, he would "say unhesitatingly that the water is, and would be, under such circumstances, a polluted water in the Mississippi and that the chances are that it would be dangerous to the City of St. Louis and the towns below.

"Q. And you believe that the best process of making this water a potable water here would be by filtration?

"A. Well, I haven't given any study to that subject particularly, but broadly speaking, that is my judgment at the present moment, yes." (2257, 2258.)

Even Mr. Whipple in his testimony in regard to the condition of the Missouri River, stated: "Insofar as the population of the watershed on the Missouri River above that point (Bellefontaine) is concerned, or insofar as the sewage of that

population is concerned, I believe it (the Missouri River) to be a sewage polluted water to the extent mentioned."

And when asked to what extent, he answered: "Insofar as the amount of sewage from the population dwelling upon the watershed enters the water of the Missouri River, and insofar as the ingredients of this sewage are not destroyed or diluted or otherwise removed from the water of the river before it reaches Bellefontaine." (2074.)

Mr. George W. Fuller, one of complainant's witnesses, gave his opinion upon the quality of the Missouri River water, in response to this question:

"Q. In considering the present, do you consider the waters of the Missouri River as a safe and usable water in their raw condition?

"A. No, sir, I do not consider the water in the Missouri River at the present time a fairly safe water." (2641.)

In addition to these statements by witnesses of complainant who testified as to the sanitary condition of the Missouri River; and in view of the fact that there has been no witness who has testified in this case that has placed the minimum amount of Missouri River water consumed by the City of St. Louis at less than 70 per cent. of the entire volume taken from the Mississippi River, it stands as an important factor in this case to be considered by the court, whether the water supply of St. Louis as the same exists at this time, eliminating the Chicago Drainage Canal, is a suitable water supply, free from infection and contamination.

Defendants assert that the evidence in this case shows that the necessity for purifying, by filtration or other means, the water supply of the City of St. Louis as the same is derived from the Mississippi River, began to exist as far back as 1866, and was so recognized by the authorities in St. Louis and has continued to be so recognized up to the present time.

Percentages of the Water of the Different Rivers at the Chain of Rocks.

Mr. John W. Hill made a calculation upon the percentages of different waters at St. Louis, and testified in part as follows:

"In order to reduce this to a more definite statement, I have prepared a table showing the relative areas of the drainage basins of the three rivers mentioned in the question, and assuming for the present that the mean rainfall would be the same over the combined drainage area of the Illinois, Mississippi and Missouri Rivers, upon this basis, and omitting all flow of Chicago sewage or of water from Lake Michigan, of each 100 gallons of water flowing in the Mississippi River opposite the Chain of Rocks 75¼ would come from the Missouri River watershed, 20 1/3 from the Mississippi watershed and the remaining 4 4/10 from the Illinois watershed.

"As a matter of fact, however, the mean rainfall over the whole area of the Missouri River watershed is not so great as that over the watershed of the Illinois and of the Mississippi Rivers, and it is probable that of the total flow of water in the Mississippi River opposite St. Louis 70 per cent. can be charged or credited to the Missouri River watershed, 20 or 22 per cent. to the Mississippi watershed, and the remaining 6 or 7 per cent. to the Illinois River watershed. In this case it is assumed that no water falls in the Illinois River except that due to the rainfall on its drainage basin.

"Q. Have you figured out the results, adding the flow from the Drainage Canal?

"A. I have upon the assumption only that the mean annual rainfall is substantially uniform over the entire Mississippi River basin embraced in the watershed of the Illinois and Mississippi River above St. Louis and the Missouri River, which is not as stated in the answer to the previous question, quite true, but for this purpose may be accepted as true. Allowing the least stream flow of the Illinois River at Grafton as reported by the United States Engineers in October, 1891, of 1,000 cubic feet per second, and assuming the discharge from Lake Michigan through the Drainage Canal of 300,000 cubic feet per minute or 5,000 cubic feet per second, and allowing for the discharge of sewage based upon 90 per cent. or 85 per cent. of the total water consumption of Chicago, which pro-

duces a discharge of 424 cubic feet per second, the percentage of volume flow with the least recorded stream flow of the Illinois River at Grafton would be seven (7). Taking this flow into consideration and also taking into consideration the flow of sewage from Chicago plus the flow from Lake Michigan. Of the water flowing in the Mississippi River opposite St. Louis, 20 per cent. would be credited to the Mississippi River, 75½ per cent. to the Missouri River and 2.96 per cent. to the Illinois River, and 1.54 to the influence of the discharge of the Chicago sewage, or such water as is carried with the sewage into the Drainage Canal exclusive of the diluting water drawn from the lake." (7543, 7544.)

Professor Keiser, at page 1033, by an algebraic formula based upon nitrites, stated that for the week ending August 21, three-fourths of the reservoir water came from the Missouri shore and the remaining one-fourth was Mississippi River water; but on cross-examination he was asked this question:

"Q. What you meant to attempt to do with that and what you do as far as the mathematical formula is concerned, or algebraic formula, is to determine that if at a given point there are .0120 of free ammonia and at some other point a certain other number of parts and at a certain other point a certain other number of parts, these two confluent sources furnish a certain ascertained amount of free ammonia at the given point?

"A. Yes, sir.

"Q. So that it is theory and not actual water?

"A. Yes, sir; it is theory." (1102.)

From the foregoing statement of Professor Keiser it is plainly evident that the percentages of Mississippi and Missouri River waters calculated as above, fail utterly to give any valuable result as to the actual quantity of water of those respective rivers entering the intake of the City of St. Louis.

Upon the question of figuring the relative proportion of

the waters of the Illinois, Missouri and Mississippi River waters upon the basis of the chemical determinations, as was done by the algebraic formula of Professor Keiser, defendants would like to submit the testimony of Professor Palmer upon that point, which is as follows:

"Q. State whether the mixing of the waters of the Illinois and Mississippi Rivers is completed by the time they reach the mouth of the Missouri River? (5454.)

"A. From certain analyses of samples of water taken in the Mississippi River about half a mile above the mouth of the Missouri River, it is my opinion that the mixing of the water of the Illinois River with the water of the Mississippi is by no means complete by the time these bodies of water reach the mouth of the Missouri.

"Q. Upon what basis could you calculate the proportional mixing of the waters of the Mississippi, the Missouri and the Illinois at the Chain of Rocks, where the St. Louis intake is located?

"A. In my opinion there is no thoroughly satisfactory basis for a calculation of the relative proportions of Illinois River water, Mississippi River water and of Missouri River water, in the mixture which passes the intake tower of the St. Louis Waterworks, but for such calculations the chlorine content would in all cases be the most satisfactory basis, because the chlorine is not a variable constituent, or rather does not vary from causes which bring about variations of all other constituents which it is customary to determine in sanitary water analysis.

"Q. Would it be practicable to calculate the mixing of the waters of the three rivers at the Chain of Rocks from the proportion of free ammonia?

"A. It would not, because free ammonia changes, sometimes rapidly, sometimes slowly, but does change as a result of decomposition of organic matters contained in the waters, in a way totally different from chlorine, and it could not be assumed with good reason that a quantity of free ammonia

found at one point or at one time would not change from processes going on within the water. On the other hand, chlorine does not change from any processes going on within the water itself, but only through the addition of more chlorine by the introduction of liquids or substances foreign to the water itself, or by concentration due to evaporation of the water containing the chlorine.

"Q. Would it be practicable to calculate the mixing of the waters of these three rivers from the proportion of nitrites?

"A. It would not for reasons similar to those just stated with reference to the ammonia. The variability of the proportions of nitrites standing in the way of the nitrites constituting a reasonably safe basis for calculation of the quantities of the water and the mixing of waters containing originally different proportions of nitrites.

"Q. Would it be practicable, then, to calculate the mixing of the waters of these three rivers from the proportions of total solids?

"A. It might be; in case the proportion of total solids were sufficiently different in the three streams which were coming together, but even then there would be very great difficulties in the way of making a reasonable approximate calculation or a reasonable approximation of the two proportions, for the reason that the total solids include matters which are in suspension, and which by reasons of variations in velocity of the stream, variations in the character of the material lying in the bottom of the stream and constituting the banks of the stream, which cause variations in the proportion of suspended matter even within short distances.

"Q. What reliability could be placed upon a calculation as to the mixing of the waters of these three rivers from the proportions of suspended matters?

"A. That would be unsatisfactory for the reason just stated in referring to the possibility of calculating the mixing from the total solids, which total solids of course include the suspended matters. The different velocities at different times

in the year and at different points even within short distances of each other, and the different character of the material with which the water is in contact, bring about in many cases a deposition of much of the suspended matters, forming, as is well known, sand bars and other deposits in the stream, and on the other hand, where the character of the banks or of deposits in the bed of the stream are such that they can be easily removed by water, oftentimes the water picks up and holds in suspension considerable quantities of foreign matters which it may derive, not from tributaries at some distance, but from localities and deposits quite near to the point at which determinations are made. That is to say, there is no certainty, and in this particular case there would be no certainty that the quantities of suspended matters found in the waters of the Illinois at Grafton would proceed down in the Mississippi River to the St. Louis Waterworks. There is no certainty that the quantities of suspended matters contained in the waters of the Mississippi above the mouth of the Illinois would remain in those waters until such time as this body of water reaches the intake of the St. Louis Waterworks, and there is no certainty that such suspended matters as are contained in the waters of the Missouri River above its junction with the Mississippi remain in that water until such time as it reaches the intake tower of the St. Louis Waterworks. For these reasons, calculations based upon the suspended solids and upon the total solids which include suspended solids, have no sound basis in fact, and on the other hand, at times the body of water passing down the bed of the Mississippi above the mouth of the Missouri may between the mouth of the Illinois and the mouth of the Missouri pick up and hold in suspension matters which would then be in excess of the quantities found in the waters of the Illinois and of the Mississippi at and above Grafton, and likewise the mixture of the three bodies of water between the mouth of the Missouri River and the intake tower of the St. Louis Waterworks, may in this stretch of six or seven miles,—perhaps eight or nine miles—pick up from the sand bars and the bank of the

river, suspended matters which were not contained at this time, at least, in the waters of either the Missouri or the Illinois or the Mississippi.

"Hence, in my opinion, it is totally impracticable to calculate the relative proportions of water from these sources contained in the mixture passing down the Mississippi River beside the intake tower of the St. Louis Waterworks, though by general study of all these constituents of the water, it is practicable to get a general idea as to the relative quantities constituting the mixture at this point; that is to say, a rough general approximation may at times be arrived at by consideration of all these constituents, as the basis for a calculation, but only a rough general approximation can, in my opinion, be arrived at from these considerations." (5457.)

Mr. George C. Whipple presented a calculation of the relative amount of water entering the intake of the Mississippi and Missouri River water, and his testimony upon the subject is as follows:

"Q. Are you for the present leaving out of consideration the turbidity of the waters, or is that entering into your calculation?

"A. In this calculation I am considering only the average results of the melosira, the cyclotella and the asterionella, and the stephanodiscus, which were found in the place mentioned.

"Q. Now, what were your conclusions?

"A. I concluded that on an average of 32 per cent. of the water which entered the intake of the St. Louis Waterworks was considered as Mississippi River water, and that 68 per cent. of the water was Missouri River water." (1938.)

Mr. George C. Whipple, who made this remarkable calculation as above set forth, and who also discovered that the Missouri River "is much more muddy than the water of the Mississippi River," (1980) made another investigation for the purpose of determining whether the water of Lake Michigan entered the intake tower of the St. Louis Waterworks. He examined the waters of Lake Michigan, the Illinois and its tributaries, the

Missouri and upper Mississippi, and the waters in the settling basins at St. Louis; and, after such examination, this question was asked him:

"Q. Mr. Whipple, assuming that at a certain time Lake Michigan water contained an organism called synedra pulchella sub prolongata variety, and that this plant is not contained at corresponding times in any of the branches tributary to the Illinois River, nor in the upper Mississippi water at Grafton, nor in the Missouri River water, and further assuming that this plant was found at a corresponding time in the water at the intake tower at St. Louis, what, in your opinion, does that show?

"A. It would show that this synedra pulchella variety sub prolongata was not derived from the water of the Missouri River or from the water of the Mississippi River above Grafton, or from the tributaries of the Illinois River, but that it came from Lake Michigan, and was borne thither by the water from Lake Michigan." (1995.)

Mr. Whipple's cross-examination is set forth as follows:

"A. I stated that there were two microscopic organisms,—vegetable plants, if you choose—

"Q. Perhaps you had better name them right there?

"A. Synedra and tabellaria, which were especially characteristic of Lake Michigan water, but not of the waters of the Missouri River or the Mississippi River above Grafton or the tributaries of the Illinois River.

"Q. Right there, now, Mr. Whipple, do I understand you to mean that those two do not exist in the waters of the Mississippi above Grafton,—those micro-organisms?

"A. No, sir.

"Q. You don't mean that?

"A. No, sir, I don't mean that.

"Q. Then they might be found, so far as you know, in the Mississippi River above the mouth of the Illinois?

"A. They certainly might.

"Q. And do you mean to say that they cannot be found or do not exist in the waters of the Missouri River?

"A. No, sir.

"Q. Do you mean to be understood as saying that they do not exist nor cannot be found, in the tributaries of the Illinois?

"A. No, sir.

"Q. Where do you generally find these micro-organisms especially?

"A. They are usually found in the waters of lakes, ponds, or reservoirs. I don't know how many lakes are situated on the Illinois River between Lockport and Grafton and have no personal knowledge on that point, and have no knowledge of whether or not there are any lakes or ponds that connect with the Mississippi River above Grafton.

"Q. If there were lakes on the Illinois River between Lockport and Grafton that connect with the Illinois River, you would expect to find those micro-organisms, wouldn't you?

"A. They might be found there.

"Q. Well, wouldn't it be reasonable to suppose that they would be found there?

"A. At times, yes, sir.

"Q. And the same is true of the Missouri River and of the Mississippi River, isn't it, under the same conditions?

"A. Yes, sir." (2019, 2020.)

It will be seen from the foregoing testimony of Mr. Whipple that he was ready to venture an opinion notwithstanding the fact that these organisms might be found in the Mississippi and Missouri Rivers; and states that the finding of them in Lake Michigan and the finding of them at the intake at St. Louis would show that they were not derived from the Missouri River water, or from the Mississippi above Grafton, or from the tributaries of the Illinois—but that they came from Lake Michigan and were borne thither by the waters from Lake Michigan. When it is considered that only three samples of water were analyzed from the Missouri River it seems somewhat remarkable that on such a meager investigation of the waters of the Missouri for these diatoms as he instituted, he would be will-

ing to draw such far-reaching conclusions. Taking this testimony in connection with the calculations as to the volume of water, the evidence seems to indicate that the most rational and reasonable method of ascertaining the relative proportions of the Illinois, Mississippi and Missouri Rivers at the intake tower was that presented in the figures hereinabove set forth by Mr. John W. Hill, which shows that, without figuring on the question of mixing, but figuring upon the volume of actual water which passed the intake tower at St. Louis, the proportions of Mississippi, Missouri and Illinois are set forth with a comparative degree of accuracy, based upon the rain precipitation taking place upon the three different watersheds.

XII.

THE OPENING OF THE DRAINAGE CANAL HAS IN NO MANNER INCREASED THE NECESSITY WHICH HAS HERETOFORE EXISTED FOR PURIFYING BY FILTRATION THE WATER SUPPLY OF ST. LOUIS, AND IN THE INSTALLATION, OPERATION AND MAINTENANCE OF A FILTER PLANT SUFFICIENT TO MEET THE REQUIREMENTS OF ST. LOUIS, THE OPENING OF THE DRAINAGE CANAL HAS CREATED NO ADDED COST.

The first time that the question of filtration came up in this controversy was when this question was asked of Professor Sedgwick:

"Q. Well, then, so far as the purification of the water of St. Louis is concerned at present, and rendering it fit for domestic use here, for drinking purposes, the expense of doing that would be the same, whether the sewage of the Sanitary District was in it or not, wouldn't it?

"A. The probable cost of doing it at present, owing to the conditions on the various rivers and at Chicago would, I should suppose, not be materially affected by the addition of the sewage of Chicago to the Mississippi River as those rivers are and as that sewage is to-day." (2258.)

But after Professor Sedgwick had thought the matter over, he took this answer back and changed his testimony upon this question and gave on page 2382, in reply to a question put to him on re-direct examination, the following answer:

"The question as I remember it, was in regard to purification by filtration, and my answer was that the cost would probably not be materially increased by the addition of the pollution and infection derived by the City of Chicago or the opening of the Drainage Canal. On reflection, however, I realize that I did not take into consideration with sufficient care the fact that aside from the masses of filth that might be washed down on certain occasions, such as freshet periods, and which would add somewhat to the cost of the cleaning of the filter and

caring for the same,—a cost which might or might not be a material increase in the conduct of those filters, according to the importance attached to the word "material,"—there is and would be the necessity for a much keener watch of the filters in regard to protection of operation, so that it might make a difference, for example, between the employment of a low-salaried and a high-salaried man as resident manager of the works. The fact is that in all our big cities using water filters, although at first it was thought that almost any one could manage them and low-priced men were often put in charge, experience is rapidly teaching us that the best men are none too good to supervise filters and safeguard the citizens against the incoming of the germs of infectious diseases. The volume of water passing through is so large that possibilities of damage by frost to the filtering material, and the possibility of channels working through the filters, and various other factors are making it every day more and more clear that we have got to have able and experienced and high-priced men in charge of these things, so that even at present I do think there would be a material increase of cost in the probable management of such filters because of the added pollution and infection from the City of Chicago. This is more particularly the case at present because there either is now or lately has been in the City of Chicago a typhoid fever epidemic, the number of deaths in the year 1902 having been larger than at any time since the great epidemic of 1890, 1891 and 1892. The actual occurrence of such an epidemic at the present time, or very lately, would of necessity be a source of the greatest solicitude on the part of any one operating filters in St. Louis during or shortly after any such epidemic, and it would be necessary to employ extraordinary care in operation and supervision of such filters even at the present time, because of the epidemical condition of typhoid fever in Chicago in 1902. Furthermore, inasmuch as Chicago has repeatedly suffered from outbreaks of the disease which can fairly be called, and have been called epidemics, the present operation of filters in the hands of any competent per-

son would require extraordinary and constant attention and skill; and such things are costly."

And when Professor Sedgwick was cross-examined upon this change of attitude in regard to the cost of filtration, these questions were asked him:

"Q. While it is evident to your mind that at any time in the last ten years the water supply of St. Louis ought to have been filtered? (2399.)

"A. Broadly speaking I should say 'yes,' although as I have just answered a question of Mr. Jeffries, there perhaps have been times when the city did get on remarkably well without it, but I think that it ought to have been filtered even then.

"Q. If they ought to have a filter it ought to be managed with great care by good men in any event, ought it not?

"A. It certainly ought.

"Q. If it ought to be conducted by good men, with great care under any circumstances, why ought it to be conducted by better men with greater care on account of the Illinois River?

"A. Simply because the added danger should require the best care possible, and greater care than would have been required with none of that river.

"Q. With typhoid germs coming down the Missouri and the Mississippi River in greater or less amounts and in varying amounts at different times, ought not the keeper of the St. Louis filters, if there were such, to be vigilant and competent at all times?

"A. Certainly, but there are degrees in this thing, and inasmuch as they got along very well without such supervision, they might, as our cities are managed in the United States, very likely have somebody who was not thoroughly up to the mark. It is a practical consideration, and if they should have such a person they would get into trouble more than they did formerly.

"Q. If the typhoid germs and the germs of other water-borne diseases were common in the water supply of any city, ought not there to be always great care and all the devices known to sanitary science exercised and used?

"A. Certainly.

"Q. If the filtration plant of the City of St. Louis was built with a view of excluding from its water supply the germs of water-borne diseases, would it have to be any better or more complex because the supposed mass of water-borne germs was greater or less?

"A. I think it would. The larger the number in the river, and the greater the amount of organic matter, the more perfect should be the construction of the filter; that is to say, for a water containing a rather low number of pathogenic germs, a more rapid rate, for instance, might be used than any one would dare to use if the water is more heavily contaminated. The filtering bed of sand, if it were a slow-sand filter, ought to be made deeper in case of a river which is rich in infection than in one which is poor in infection. I think it would really practically add to the difficulty of construction and operation." (2402.)

This testimony on filtration, accurately speaking, shows Professor Sedgwick's double-barreled position upon this proposition:

The value of his opinion in regard to the matter concerning which he was testifying is best expressed by himself when he was asked this question:

"Q. Well, if you have any opinion as to what proportion of that expense should be attributed to the waters of the Illinois, state your opinion?

"A. I haven't any; at least I haven't anything worth stating in figures." (2401.)

The next witness was Mr. George W. Fuller, who stated his views in regard to the additional cost of filtering the water of St. Louis with the sewage of Chicago as follows:

"In my judgment, the increased amount of infection coming into the Mississippi River from the City of Chicago's sewage at the present time makes an added responsibility as regards the treatment of that water, to make it perfectly safe and wholesome as supplied to the citizens of St. Louis. Such

treatment of the water would involve, I think, at the present time, more responsibility, and in a financial way it would be shown by the greater expense of supervision of a filtration plant, and the added cost of supplies used in connection with the operation of filtration work, especially at times of low water. It would also mean that such filtration work, if adopted, would be operated from time to time, if not regularly, at lower rates of filtration than if this increased infection were absent. The significance of this is that by reducing the rate of filtration, that a larger plant would be required, and hence a more expensive installation for filtration work, to purify the same quantity of water, than in the instance of water without this added infectious matter." (2624.)

And upon cross-examination Mr. Fuller was asked these questions:

"Q. What would be the cost or amount to operate such a plant as that filtering the waters of the Mississippi and Missouri Rivers?

"A. I am afraid I cannot dictate the terms of compensation for those men.

"Q. Have you any idea about it?

"A. I should think between the limits of $2,500 and $5,000 a year; I don't know exactly.

"Q. Do you know of any man in the United States to-day that operates a filter such as would be operated here, in filtering the waters of the Illinois, Mississippi and Missouri Rivers?

"A. I am not personally acquainted with such a man.

"Q. What in general would be the added expense of such a plant, covering the waters of the Illinois, the Mississippi and Missouri, over a plant filtering the waters of the Mississippi and the Missouri, taking the whole matter together and under present conditions?

"A. I haven't made any close figures on that. I should think it would amount to quite a number of thousand dollars each year.

"Q. Well, how many?

"A. It is a mere guess which I would give; perhaps $20,000 or $25,000 for an off-hand opinion.

"Q. Would you recommend a less skilled man for the filtration of those waters than you would if the Illinois was added?

"A. Yes, that is, experience and skill, combining the two.

"Q. Under present conditions, what percentage of Illinois River water enters the St. Louis intake through the year?

"A. I don't know accurately on an average. It varies very much, no doubt." (2637-8.)

Mr. Allen Hazen, another witness called by complainant in this case, testified on cross-examination as follows:

"Q. In the construction of filters is there any additional cost for a filter for the filtering of bacteria?

"A. There may be.

"Q. Aside from the filtering of mud?

"A. There often is additional expense. In the case of St. Louis there would not be materially." (2844.)

And again Mr. Hazen states:

"Q. When you took into consideration the various conditions at St. Louis to be overcome did you take into consideration the fact that the supply of water at the intake came from the three rivers, the Missouri, Mississippi and Illinois Rivers?

"A. I did.

"Q. Were you aware of the fact at that time that the Drainage Canal had been opened and the sewage of Chicago was emptied into the Desplaines River?

"A. Yes, sir.

"Q. You took that into consideration?

"A. Yes, sir.

"Q. Would the cost be reduced somewhat if you could eliminate the water that comes into the Desplaines River from the Drainage Canal?

"A. Not materially." (2851.)

The testimony of Mr. Hazen to the effect that the sewage of Chicago would not add materially to the cost of a filtration plant

such as he recommended in his report in 1902, is given after he had considered this matter of cost in his official capacity as a commissioner appointed to pass upon the question of a filter plant to be established at St. Louis. And the testimony of Mr. Fuller, as above partially quoted, in view of Mr. Hazen's position, both of them being witnesses for complainant, becomes significant when we read that Mr. George W. Fuller, in commenting upon Mr. Hazen's statement in the report which he made to the City of St. Louis in regard to filtration, says:

"With regard to this method of purification for the St. Louis water supply, it is my judgment that it will yield a water of satisfactory appearance and hygienic quality with proper construction and operation of the works and that it is the best and most applicable method for the conditions existing at and near the Chain of Rocks." (6956.)

If Mr. Fuller, who endorsed the plan submitted for the filtration of the water supply of St. Louis by Mr. Hazen in the glowing terms above quoted, had given the question of cost as much consideration as did Mr. Hazen, it seems almost incredible that he could have arrived at the conclusions testified to by him in his evidence in this case upon the subject of cost of filtration.

The next testimony offered by complainant upon the subject of filtration was that given by Dr. Herbert E. Smith in his testimony, wherein he gave his views as follows:

"Taking into consideration the fact which you have called to my attention, I would state it as my opinion that the installation and operation of a filter plant at St. Louis would be more expensive by reason of the discharge of the sewage from Chicago into the Illinois River, and that if the deleterious agents in this sewage were removed that the cost of the installation and the maintenance of a filter plant at St. Louis would be lessened." (7723.)

As to his competency to presume to pass judgment upon the subject of filtration, defendants would like to call the Court's attention to the cross-examination of this witness upon this point, which is as follows:

"Q. Have you ever operated a filtration plant? (7744.)

"A. I have never operated one in the sense of having charge of the works. I have, of course, made analyses showing the character of the work.

"Q. Have you had anything to do with the engineering features of a filtration plant?

"A. No, sir.

"Q. Have you ever accepted bids for the installation of a filtration plant or passed upon the reasonableness of the bills?

"A. I have never been called upon to pass upon such matters when they are engineering matters.

"Q. Have you ever employed men to operate a filtration plant and passed upon the reasonableness of their compensation?

"A. I have never been called upon to make such decisions, no, sir.

"Q. Are you acquainted with what it cost to operate a filtration plant filtering 200,000,000 gallons of water per day?

"A. In a general way I know the cost of filtering water, but it differs under different conditions, and as I give little or no attention to the engineering side I have not paid special attention to that.

"Q. Have you had any experience in filtration plants in the Mississippi River valley?

"A. No, sir.

"Q. Are you acquainted with the number of men necessary to operate a filtration plant?

"A. Why, in a general way I am.

"Q. Is that information based upon actual experience in the employment of men, figuring out the cost of the filtration plant?

"A. No, sir; that has to do with the administration and engineering features, of which I have had no experience.

"Q. If you have had no experience in the engineering and administration whatever of a filtration plant, wherein does the element of cost come in, in operating a filtration plant when

infection is present in the water, together with matters in suspension that are to be removed?

"A. The chief sanitary object of filtering water is to remove the infection. The questions relating to the rapidity of filtration, the character of the filtration, the scientific oversight of the operation of the filter, all depends upon the relative contamination of the water which has to be filtered. In other words, a water which has a certain or given contamination would be satisfactorily filtered at a certain rate. If the water had a greater amount of contamination then the rate, in order to accomplish the removal of the obnoxious parts, with the same degree of thoroughness, must be as a bacteriological factor slower, and it will take a larger plant to filter the same amount of highly contaminated water than it would of a less contaminated water. Then further, as filters are liable to fail in their operations at times, a filter which is filtering water highly contaminated must have more careful scientific oversight in the way of the testings of the water to get at the general character of the water.

"Q. Is it not a fact that the chief cost in the establishment and operation of a filter depends upon the matter in suspension, and the question of infection is a matter of secondary consideration?

"A. Not from a sanitary standpoint, no, sir.

"Q. What city in this country is operating the largest filter plant?

"A. The plant which is operated in part in Philadelphia is one of the largest plants in the country, I believe.

"Q. Do you know whether the waters of the Schuylkill and the Delaware Rivers are any less infected than the waters of the Mississippi as they pass St. Louis? (7745.)

"A. The typhoid death rates of the two cities are both pretty high. The typhoid death rate at Philadelphia is higher than the typhoid death rate at present in St. Louis, and from that standpoint I should judge that the water which is used in the raw state supplied in Philadelphia is a more contaminated water than that which has been supplied to St. Louis.

"Q. Have you ever given the question consideration as to the difference in cost between a water that is sewage polluted, greatly charged with matters in suspension, and a water of equal pollution that has infection present as to difference in cost of operation and maintenance of a filtration?

"A. As stated, those are matters which pertain to the engineering side of the problem, and I have not given the details of such matter attention.

"Q. Then, doctor, how were you able, in your examination, to pass an opinion as to the relative cost of filtration here in St. Louis with the waters of the Drainage Canal turned in over conditions that obtain if the sewage of Chicago was eliminated?

"A. The opinion which I expressed regarding that was a *general one* in regard to the relation, and not a *specific one* which would require the knowledge of an engineer, and was based upon the considerations which I enumerated a short time ago relating to the question of rapidity of flow through the filters as affecting their size and the oversight as affecting the character of the effect from a sanitary standpoint, and I did not mean to express it on any other facts.

"Q. The opinion, then, was very general?

"A. It was general that it would cost more on these accounts.

"Q. Have you any specific knowledge that justifies you in expressing such general opinion based upon your experience in matters of filtration and filter plants?

"A. I know that it is customary in connection with the filter plants of the various cities in Europe to operate them according to the results of the bacteriological examinations. If the tests show a larger proportion of bacteria on a given day, that is taken as evidence that the filter is passing the water too rapidly for a satisfactory purification, and then the rate is modified accordingly, and this varies with the number of organisms in the raw water to be filtered." (7747.)

The foregoing testimony of Dr. Smith demonstrates that he

gave an opinion upon a proposition concerning which he had no knowledge or experience to justify him in his conclusions, and the value of his opinion upon the subject under consideration is therefore nugatory. He had had no experience with any part of a filtration plant, according to his own testimony, that was connected with the matter of cost, and it should occasion surprise that a man of science would venture an opinion upon such a highly technical matter as the construction cost of filters with the limited practical knowledge he possessed.

The next witness who testified upon this subject on the part of complainant that it would cost more to install and operate a filtration plant at St. Louis with the sewage of Chicago present than it would if Chicago sewage was eliminated, is Mr. John W. Alvord. Mr. Alvord was a witness who was placed on the witness stand in rebuttal after defendants had closed their case, and his testimony upon the subject of the cost of filtration was objected to by defendant for the reason that it was part of complainant's original case, and the subject matter of the question of filtration was gone into in detail by the other witnesses who took the stand for complainant in putting in their original case. It was, therefore, not proper rebuttal and was consequently incompetent. Over the objection of defendant he testified as follows:

"In my opinion, the presence of sewage from the Sanitary District of Chicago in the waters of the Mississippi River at the Chain of Rocks makes it more costly to provide suitable water for domestic purposes for the City of St. Louis.

"Q. In what respects is the water supply of St. Louis made more costly or difficult by virtue of the opening of the Drainage Canal?

"A. The design and construction of a purification plant dealing with a seriously polluted water, especially of one of known high typhoid pollution should be more complete and delicately adjusted to its work than when dealing only with water of rare infection and presenting less dangerous difficulties, such as turbidity and color." (7791.)

On cross-examination he testified, in answer to questions, as follows:

"Q. Would you put men in charge of a filter plant with less capability and experience if the sewage of Chicago was eliminated than you would if it were present?

"A. Not to any very marked degree. I should think I would be a little more cautious and would recommend a little greater expense, but I do not think that the difference in the cost of filtration would be very much affected by that particular item.

"Q. In the construction of the filtration plant at Philadelphia,—which is the largest in the United States, is it not?

"A. Yes, sir.

"Q. Do you know whether there is any element of cost entered into in that plant in order to guard against infection?

"A. Yes, I think the preliminary filters can be properly so considered.

"Q. If John W. Hill, who was constructing that plant, should testify that infection was no element of cost in the operation and installation of that plant, would his opinion have any weight with you?

"A. I think I should be disinclined to agree with him.

"Q. Have you constructed any filter plants wherein you have made additional cost to guard against infection?

"A. I do not think I have personally, with this exception: that I have provided for the filtration of sewage as well as the purification of water in a plant deriving its water supply from the same source into which it emptied the sewage." (7816-17.)

His cross-examination further develops the fact that the only filtration plant that he ever constructed was one situated in the small town of Lake Forest, Illinois, one of the suburbs of Chicago, which was a mechanical filter costing about $7,000, and that he had designed a set of plans for a private company for Ottumwa, Iowa; these plans have not been accepted, and according to his testimony, "the chances are against it." And it is a significant fact that the only filters that Mr. Alvord was

personally responsible for and connected with in a personal capacity were mechanical filter plants, which are patent filters, and according to his own testimony, using his own language, "my personal connection with the design and construction of filter plants has been rather more limited than my experience in the design and construction of sewage plants."

"Q. But in the active construction and building of filter plants, where you have figured on cost and were responsible for the filters, are these the only two plants that you have been connected with in that way?

"A. I believe they are." (7818.)

While his testimony, according to the position taken by the defendants in this case, is not rebuttal, and therefore incompetent, nevertheless, based upon his lack of personal experience in *doing things* in connection with filtration, the defendants contend that his opinion is not backed up by sufficient first hand knowledge to justify his conclusions on the subject of cost being accepted.

The foregoing testimony quoted above emanates from witnesses called to the witness stand by the complainants in this case. In rebuttal of this testimony the defendants in this case called to the witness stand Mr. John W. Hill, who has charge of the installation and operation of the filtration plant in the City of Philadelphia, the largest plant that has ever been constructed; also Professor E. G. Smith, of Beloit, who has had more experience in the installation and operation of filtration plants than any other one man in the central west. Reference to his qualifications will justify this assertion. The defendants also placed upon the stand Mr. Rudolph Hering, the father of the Drainage Canal, a partner of Mr. George W. Fuller, and a man who has been connected with larger enterprises, viewed financially, than any witness who has testified in this case; also Professor W. P. Mason, of Troy Polytechnic, who has had a large experience in connection with the subject of filtration.

Defendants would like to call the Court's attention to the testimony of Mr. John W. Hill, above referred to, which is as follows:

"Q. If in your opinion the water supply at the Chain of Rocks, which consists of the combined waters of the Illinois, Mississippi and Missouri Rivers, is an unsafe and unfit water for drinking and domestic purposes in its raw state, or as treated at the present time by the settling basins of St. Louis, what is your opinion as to how said water should be treated in order to get a safe and wholesome water for drinking and domestic purposes? (7558.)

"A. By filtration.

"Q. In passing upon the question of filtering the water at St. Louis, assuming that as an engineer having this problem under consideration, what consideration would you give to the *sewage entering the Drainage Canal from Chicago* in passing upon the question of filtration at St. Louis?

"A. *No special consideration* would be given the sewage of Chicago running into the headwaters of the Illinois River, which forms one of the tributaries of the Mississippi River.

"Q. From your investigation of the water supply at St. Louis, which takes its water from the co-mingling of the Illinois, Mississippi and Missouri Rivers, at the intake tower at the Chain of Rocks, what conclusion do you draw as to how that water supply compares with the other water supplies of the cities of this country and in Europe with which you are acquainted? (7562.)

"A. I have made a comparison of the conditions of the three cities, namely, St. Louis, and Philadelphia with reference to the Schuylkill River alone, and Hamburg, Germany, drawing its water supply from the Elbe River.

"Q. Assuming that the City of St. Louis drew its water supply wholly from the Illinois River drainage basin?

"A. I have considered the total drainage area of each of the three drainage basins. That is, I have considered the urban and total population on each of the drainage basins, and I have finally developed the factor in the manner explained in the answer to the previous question, which, in my opinion, shows the relative advantage or disadvantage of the source of water sup

ply of the three rivers mentioned with respect to the three cities drawing their water supply wholly or partly from the sources under consideration. The size of the numbers thus obtained indicates the objection to each source of water supply as follows: For the City of St. Louis, on the assumption that the water supply is drawn only from the Illinois River basin, there is 209.20; of the City of Philadelphia, upon the assumption that the source of water supply is drawn from the Schuylkill River, 330.63; and for Hamburg, which draws its entire water supply from the Elbe River, 698.12. The lower figure by this method of comparison would indicate the best source of water supply, and if my method of reasoning is correct it would show that under the present conditions the Illinois River would be a safer source of water supply for the City of St. Louis than is the Schuylkill River for Philadelphia or the Elbe River for Hamburg. The water of the Elbe River at Hamburg is now and has been for eleven years past all filtered. Preparations are going forward to filter the water supply at Philadelphia from the Schuylkill as well as from the Delaware River. And by the same process of reasoning it seems to me that the water supply of St. Louis should be filtered in order to remove any natural objections that exist to the sources from which its water is taken.

"Q. Would it cost any more to filter the water of the Mississippi River at the Chain of Rocks with the water of Chicago entering the Drainage Canal, as it now does, than it would if the said sewage of Chicago was eliminated?

"A. *It would make no difference whatever, either in the cost of construction or the cost of operation of a system of filters for the City of St. Louis.* From a reasonable experience in constructing and operating works of filtration on a large scale it is clearly shown that the sewage pollution of a river is not the feature that increases the cost of filtering a polluted water. That material which rapidly clogs the filters, requires their cleansing from time to time, is mud and silt flowing in the river and represented in the analysis as suspended

matter, of which the bacteria from sewage sources constitute by weight or volume an infinitesimal part. It is not known that what we term mud, excluding bacteria, is in itself a particularly objectionable element in water, at least it is not known that it is the cause of disease or disorders in the human system, and is chiefly if not wholly objectionable from an æsthetic point of view.

"I feel that the experience at Philadelphia with the filters that have been operating at the Roxborough stations, some of them for 21 months and others for a period of nine months, in daily service, dealing with upwards of 23,000,000 gallons of water per day, showing clearly that the varying degrees of pollution in the Schuylkill River as determined by the bacteriological and chemical analyses have no influence whatever either upon the efficiency of the filters, or their cost of operation, but when the Schuylkill River is in flood and large quantities of clay and soil are being brought down from its drainage basin to Philadelphia, this material does have an influence in affecting the cost of operating the filters, and to a limited extent has some influence on the efficiency, at least with reference to the turbidity of the water filtered.

"Q. Applying the experience which you have had with the Schuylkill to the waters of the Mississippi River as the same pass the intake and the knowledge which you have of the three rivers, the Illinois, the Mississippi and the Missouri, which one of the three rivers thus mentioned would create the largest percentage of cost in operating a filtration plant at St. Louis?

"A. *The Missouri River*, by reason of the very large amount of suspended matter brought from its watershed and contributed to the suspended matter of the mixed waters of the two other rivers opposite St. Louis; and the difficulty of filtration of the St. Louis water will be found to be wholly due to the silt and other suspended matter in the Mississippi water at St. Louis, obtained very largely from the Missouri River drainage basin. The sewage condition at St. Louis, I should regard as involving no special difficulty whatever, and I base this

opinion upon careful study of the report of the last commission of engineers appointed to investigate the water supply of that city.

"Q. That was the Merrimack Commission?

"A. Yes, sir.

"Q. Who made that report?

"A. That report was made by a commission consisting of Benezette Williams, of Chicago; Mr. George Y. Wisner, of Detroit, and Allen Hazen, of New York.

"Q. That is the report where Mr. Hazen filed a minority report, defending the filtration of the Mississippi River?

"A. Yes, sir; that is right. The majority of the commission recommended the Merrimack scheme.

"Q. Would the Mississippi and Illinois, exclusive of the Missouri River, cost as much to filter as the Missouri?

"A. No, they would not, for the reason that the percentage of suspended matter is lower in each of the two rivers, namely, the Illinois and Mississippi River, than it is in the Missouri River. It would not cost as much because of the lower percentages of suspended matter in the two rivers mentioned.

"Q. *Would the amount of infection in the river, meaning by that sewage infection, create an added cost to the operation of the filters?*

"A. *No, it would not.* If the water through a system of filters was free from sand and silt and soil that can be charged to the wash of the banks of the river or of the watershed of the river, what we would term city sewage could be filtered, provided it was mixed with the same volume of water as that flowing in the stream into which it is discharged. In cleaning filter beds such as are in use in the City of Philadelphia and elsewhere it is found that practically all of the material moved from time to time would be classed as mud, and if it were possible to so separate this mud at the surface of a sand bed into organic and inorganic material, and include the bacteria as a part of the organic material, the organic matter would bear such a small relation to the total amount of material collected

that the cost of filtration prorated on this would be an insignificant amount, and after all the real cost of operating filters is represented by the efforts to remove from a polluted water the suspended matter exclusive of the bacteria, and that matter which usually imparts turbidity to the water.

"Q. *If a water should be highly infected with typhoid germs, would the fact that the water was highly infected create any added cost in the construction or operation of a filter?*

"A. *None whatever.* (7566.)

"Q. Assume that a filter plant should be established at the City of St. Louis sufficient in size and suitable for the demands required, would the fact that the Mississippi River at the Chain of Rocks varies from time to time from slight infection to large infection create any added cost in the operation of such filter?

"A. None whatever.

"Q. Would it require any more skill and expensive operators to handle a filter that would meet the demands of the City of St. Louis under low infection than it would under a high infection existing in the waters of the Mississippi River under present conditions?

"A. The degree of sewage pollution or of infection of water coming to the filters would not be a factor either in determining their cost of construction or cost of operation. Evidence along this line is best shown, in my opinion, by the regular tests which I am having made of the raw waters applied at our Roxborough filter station, and of the filtered water afterwards to determine the presence of the colon bacillus, deeming this a more delicate test of the operation of sand filters than the comparison of numbers of bacteria in the water before and after filtration. These tests which are regularly made two or three times each week reveal the fact that upon exceedingly rare occasions is the colon bacillus found in the filtrate of any filter while we seldom fail to find it in the applied water. Reducing the operation of the filters with respect to the colon bacillus to percentages, it shows that under the worst conditions

of the operation of our filters we have removed from 96 to 99 per cent. of the colon bacillus and in making this determination I am excluding from consideration altogether a great majority of the times when it is not found at all in the filtrate.

"Q. In passing judgment upon the value of a water supply as based upon the population does that judgment take into consideration the condition of the river as determined by the chemical and bacterial condition of the water and the volume of flow?

"A. No, it does not and is based solely upon the factors noted, namely, the area of watershed population on the watershed considered as an entirety, population gathered in the urban cities of 4,000 or more people and finally the distances of each of these centers from the water intake.

"Q. How does that method which you have just indicated compare with the chemical and bacterial examination covering a long period of time of the waters of the river and the volume and size of the river?

"A. Excluding the soil, grains of sand and silt which are found in varying quantities in different rivers, and excluding the difference in the volume of flow of such rivers, it must be held and is held at times that the chemical condition or bacterial condition of the several rivers so compared would be substantially the same. That is to say that the sewage pollution of the stream would depend upon the number of people contributing to it, other things equal; 2,000 people would be a greater objection upon a given watershed than 1,000 people, and the probable sewage going into the stream would be twice as great from 2,000 people as from 1,000 people. By this process of reasoning it would be fair to assume the sewage pollution of any stream bears a just relation to the population gathered upon its watershed when modified by the distance of center of population from a proposed point of water intake. The chemical and bacteriological investigations show in reference to the City of St. Louis that the Illinois River is a better source of supply, while the physical investigation that has been described show that it is the least desirable source of supply. If we had

no chemical and bacteriological data and were approaching the problem as a new proposition we would fix the center of population of the Illinois River watershed nearer the St. Louis intake than that of the Mississippi and Missouri watersheds. This mode of comparison of watersheds wholly ignores the volume of flow in each stream.

"Q. Where the information is obtainable showing the chemical and bacterial conditions of the river, and its volume of flow, and the information is also obtainable showing the population upon the watershed in the methods here described of a given river, which method furnishes the most accurate way of arriving at a correct judgment of the quality of such a river?

"A. The technical analyses of the water itself at any definite point?

"Q. *In considering the question of filtration as applied to St. Louis, would the percentage of water passing over the bear-trap dam at Lockport, which represents the mixed sewage of Chicago and the water of Lake Michigan, as the same arrives at the Chain of Rocks at St. Louis, commingling with the waters of the Illinois, the Mississippi and the Missouri Rivers, be a factor of expense either in maintenance or operation or installation of a filter established for the filtration of a municipal water supply of the City of St. Louis?*

"A. *It would not.* (7568.)

Cross-Examination by Mr. Jeffries.

"Q. What are the elements of cost so far as the condition of the water is concerned in the construction and operation of a filtration plant?

"A. The element of cost in the construction will be the area of filters required to deal properly with the given water. The element of cost in operation would be represented by the period of operation of the filters between successive cleanings and the amount of material to be scraped and cleaned from the filters at the end of each such period, that is to say, with a water carrying large amounts of suspended matter, the rate of filtra-

tion per unit of surface would be less than with a water carrying smaller amounts of suspended matter.

"Q. Why is it necessary to clean the filters?

"A. Because of their becoming clogged at the end of what is termed the period of operation.

"Q. What would be the result if they were not properly cleaned?

"A. The filter would fail to deliver the required amount of water by reason of the clogging of the sand bed at the surface.

"Q. Would this clogging in any way produce a perversion of the sand bed?

"A. No, it would not; it would simply create a mass of matter in the interstices of the sand bed at and near the surface such as to prevent the usual rate of flow per unit of sand area.

"Q. Is this unit of sand area graduated by the amount of infection that is supposed to exist in the water?

"A. No, it is not. It would be graduated entirely by the total amount of suspended matter found in the water as an average through the year of operation.

"Q. The more suspended matter—

"A. The larger the area to filter a given amount of water, because of the smaller rate of percolation per square foot of sand.

"Q. *As to the depth of the sand bed, what bearing has the infection upon the necessary depth?*

"A. *None whatever.* In fixing the thickness of sand beds I do not know that the possibility of infectious matter in the water has been a factor, if taken into consideration at all. As a matter of fact the sand beds are of varying thickness in filters built by different cities. They are likewise of a varying size of sand grains within reasonable limits. The custom is when a new filter has been constructed to furnish it with a maximum thickness; a sand bed which for this purpose may be put at 40 inches in depth. Such sand bed is scraped from time to time as the filter is taken out of service until the least thickness is seldom less than 20 inches, such a filter is once more scraped and

the entire bed of sand is restored to the original thickness of say 40 inches.

"It is believed, and I think proven by my personal experience, that filtration is as well accomplished with a 20-inch sand bed as with a 40-inch sand bed, but it is doubtful to my mind as to whether thicknesses of less than 20 inches could be used in order to insure at all times a satisfactory quality of filtered effluents.

"Q. Is it not a fact that water sometimes becomes very greatly infected and requires double filtration?

"A. There are examples, notably at Bremen in Germany, where the water is run first through one filter and then through another filter of the same size, in which the rate of percolation is maintained the same as in the former filter. This is with a view to improving the quality of the filtrate. The same method or custom prevails in the waterworks at Schiedan, Holland. In our waterworks at the lower Roxborough station all the water is twice filtered, once at the high rate through roughing filters and a second time at a low rate through the plain sand filters. In the Philadelphia experience, however, this is done in order to admit of a reasonable and a normal rate of percolation in the second set of filters and not primarily with a view to guarding against unsatisfactory filtration of the water in the second set of filters. It may be said with reference to the Philadelphia experiments that the water from the primary or preliminary filters is not regarded as satisfactory for use at any time.

"Q. In the construction of a filter plant do you take into consideration the character of the watershed, the volume of water in the stream, together with the chemical and bacterial determinations of that water?

"A. In fixing the preparations and method of operation in filters, no consideration is given to the area of the watershed or to the population gathered upon it. And this condition would form a factor only for the purpose of comparing conditions as between two proposed sources of supply. The final factors that would enter into consideration of the size and method of opera-

tion of filters would be determined by the chemical and bacteriological analysis of samples of water taken from the selected stream or other source of supply at the proposed point or existing point of intake.

"Q. In the operation of filtration plants is it customary to entirely eliminate all bacteria from the water?

"A. Eliminate all from the filters?

"Q. Yes.

"A. Upon rare occasions it has been shown that the entire number of bacteria have been eliminated from the filter effluents. That experience has been had with our own filters here in Philadelphia and has also been had with the filters in London: As a general proposition, however, there is remaining in the water after filtration very rarely more than one or one and a half per cent. of the original number of bacteria found in the applied water.

"Q. And that percentage varies according to the efficiency of the plant and its operation?

"A. It does.

"Q. The more infected a water becomes the more important it is for a thorough and efficient construction and operation of a filtration plant, is it not?

"A. The degree of infection in the water would not affect the cost of construction but it would affect the grade of sand used in charging the filters with filtering material. If the source of supply is known or believed to be materially infected it should call for greater care and vigilance in the operation of the filters. That is to say, if filtration has for its object the removal or material reduction of sewage pollution in the applied water it would require denser beds of sand and more care in the operation than if the sole purpose was to remove suspended matter not of a deleterious character, or for the purpose of removing simply mud from the water, but this does not necessarily involve either increased cost of construction or increased cost in operation.

"Q. It may do so, however?

"A. It is not likely, Mr. Jeffries. The result would be to reduce the size of sand in the bed, that is to say it would be a denser bed, not quite so coarse, and it would demand closer attention on the part of the filter manager who should keep in close touch with the daily operation of the filters.

"Q. And as you reduce the size of the grains of sand, or as you employ denser beds of sand, the slower the process of filtration becomes, does it not?

"A. That would be true, provided there is no preliminary filtration of the water, such as we have made a part of the system of filtration for Philadelphia.

"Q. Is it not true that water would percolate through rough grains of sand more rapidly than through dense grains of sand?

"A. It will.

"Q. A given quantity of water will pass through a bed of sand consisting of coarse grains more rapidly than through a bed of sand composed of fine grains?

"A. It will. The rate of percolation will be most rapid in the more porous bed of sand.

"Q. And as the degree of diminution in the character or size of the sand grains the slower the process of filtration upon a given area?

"A. That is true."

(See Hill's testimony, Vol. 8, pp. 7558-72.)

Professor E. G. Smith, who has had connection with more filter plants along the Mississippi River than any man in this western country, testified upon this question as follows:

"Q. In the event that a filter plant should be established at St. Louis for the purpose of filtering the water of the Mississippi River, which includes the combined water of the Mississippi and Missouri rivers, would the installation of such a plant, in your opinion, cost any more to build and construct and operate with the waters of the Illinois, since the opening of the Drainage Canal, emptying in the Mississippi River than it would prior to the opening of the Drainage Canal.

"A. From my knowledge of the Mississippi River, as based

upon personal investigations and chemical and bacteriological examinations of the same, and from my study of the analyses of the Illinois River at Grafton, before the waters of the same are discharged into the Mississippi River water, I am very clearly of the opinion that the cost of purification of water below the mouth of the Illinois River would not be increased, owing to the waters of the Drainage Canal finding access to the river, and therefore the cost of installation and operation of a filter plant at the City of St. Louis would not be increased owing to the admission of waters from the Drainage Canal.

"Q. In the construction of such a filter plant at St. Louis, which one of the waters of the three rivers, the Illinois, Mississippi or Missouri, if treated with a filter plant, would cost the most for filtering?

"A. The answer to the question cannot be made in brief. It involves the whole question of the type of filter most desirable to use, whether a mechanical filter or a system of slow sand filtration, the amount of previous treatments by sedimentation; an exact answer to that question, involving, as it does, these rivers, could be made only after a series of experiments upon the rivers themselves and upon a large scale. As an illustration the cost of purifying the Ohio River at Cincinnati was determined only after a large experiment, and also after an elaborate series at Louisville, Kentucky; also after an elaborate series of experiments upon the Allegheny River in determining the treatment of the water supply at Pittsburg, the Allegheny forming one of the tributaries; the proper course to pursue at New Orleans, the type of filtration to be adopted, was determined only after an elaborate series of experimentation. Therefore the full answer to that question involves data which is not at hand.

"Q. If a filter plant should be established at St. Louis to filter the combined waters of the Illinois and Mississippi and Missouri rivers would such a plant require any change in its construction or management if the Drainage Canal should be closed?

"A. From my knowledge of the quality of the Mississippi River water and the difficulties met with in successfully filtering the same; from personal study upon filter plants and upon the river; the water of the Illinois River at Grafton being so similar to the waters of the Mississippi River; the waters of the Illinois River at Grafton being, in my opinion, essentially the same as they were before the waters from the sewage of Chicago were delivered from the Drainage Canal into the Illinois River, I am clearly of the opinion that the role which the Drainage Canal plays in the Illinois River would not affect the cost of installation, management or operation of a filter plant filtering the waters of the Mississippi River at St. Louis after the same have received the Illinois River at Grafton and the Missouri at a point below.

"Q. If such a filter plant should be established at St. Louis would the cost of operation be increased because of the opening of the Drainage Canal over conditions that would obtain if the same was not opened, and would it require any more skillful and expensive operators to work the filter with the Drainage Canal opened than if the Drainage Canal was closed?

"A. From my knowledge of the quality of the Mississippi River water and the difficulties met with in properly filtering the same, from personal study and observation at other points, and from my knowledge of the quality of the Illinois River at its mouth, as disclosed by observations, both chemical and bacteriological, made both before and after the Drainage Canal was opened, the same showing the Illinois River to be essentially of the same general character as the Mississippi River water, I am clearly of the opinion that it would not cost any more to operate a filter plant or require more skill and expensive management of the same after the sewage of the City of Chicago had passed through the Drainage Canal into the Illinois River and thence into the Mississippi River water above St. Louis than before the Drainage Canal was opened." (6794-6796.)

Mr. Rudolph Hering, a partner of Mr. George W. Fuller,

an engineer of eminent qualifications, testified upon the cost of filtration as follows:

"Q. What experience have you had in the filtration of water and the construction of filters for municipalities?

"A. I have taken considerable interest in the matter from the time I first visited some European filters in 1881. I was acquainted with Mr. Hyatt, who invented the first rapid or mechanical filter, and introduced the same in this country, and always anticipated some advantage to be gained from such a method of rapid filtration, and have followed the advances of mechanical filtration ever since. I studied the methods of slow filtration on the ordinary European method and in connection chiefly with the water supplies of Philadelphia and New York, in both of which cases I recommended the slow sand filtration for adoption. I was also asked to pass upon the method of filtration to be adopted at Washington, D. C., in connection with Mr. George W. Fuller and Mr. Allen Hazen, we three making the report. I have gone into the subject of filtration as thoroughly as I know how.

"Q. Are you acquainted with the cost of building filter plants?

"A. I am.

"Q. Are you acquainted with the cost of operating filter plants?

"A. I am.

"Q. What is your opinion as a sanitary engineer whether it would cost any more to filter the water of the Mississippi River at the Chain of Rocks, which consists of the combined waters of the Illinois, Mississippi and Missouri rivers, with the sewage from Chicago emptying into the Drainage Canal and from thence into the Illinois River than it would if such sewage was eliminated from the Sanitary Drainage Canal?

"A. In my opinion it would make no practical difference in the construction method or cost, nor in the method and cost of operation.

"Q. As a sanitary engineer passing upon the quality of

the Mississippi River as it passes St. Louis and the Chain of Rocks, what facts would you take into consideration in passing upon the quality of that water in its raw state?

"A. The chief object that would first appeal to me which I would have to get some satisfactory answer and solution is the turbidity of the water, because that affects the manner of treatment more than anything else, and then, of course, I would also consider the pollution of the river by the number and kind of bacteria contained in the water. I would also be governed by the hardness of the water or any mineral content of different kinds. I would have to know what the water was, both chemically and bacteriologically and physically, before I would feel that I was completely and satisfactorily solving the problem.

"Q. Taking the data which you have introduced in evidence, what help would that data be to you in considering such a problem?

"A. These data would indicate to me that first and foremost a filtration of the water was necessary, due to the probability that typhoid bacilli would reach St. Louis to a large extent from the Mississippi and Missouri and to a less extent from the Illinois River.

"Q. *What consideration would you give to the sewage coming from Chicago?*

"A. *I should give no consideration at all, because it was a small factor in the problem. It was too small a factor in this problem to materially affect any recommendation.*

"Q. In the operation of such a filter plant that would be established to meet the demands of the people of St. Louis for a pure and safe water supply, would the operation of such a plant require a higher degree of skill or more expensive men to manage and operate such a plant with the sewage of Chicago emptying into the Illinois River than it would if such sewage was not present in the Illinois River through the Drainage Canal?

"A. It would not. (7007.)

Cross-Examination by Mr. Jeffries.

"Q. Mr. Hering, what is it that enters into the cost of a filtration plant and the precautions that are to be used in connection with its operation as applied to the character of the water that is to be filtered? (7030.)

"A. The first question usually related to the turbidity of the water; that is, as to the amount of suspended matter carried by such water, because the system of filtration to be recommended largely depends upon the turbidity of the water. The next chief question relates to the relative expense and the topography, the conditions, the availability or non-availability of sand, which sometimes throws the scale one way or another in deciding upon the method of filtration to be adopted.

"Q. In the event a filtration plant was established for the purpose of filtering the water of a certain city, and that at some point above that city a typhoid epidemic should be prevalent, why has it been deemed necessary for the management of the filtration plant to use extra precautions during such epidemic?

"A. The running of a filter plant, like the running of any plant, can be somewhat variable, owing to the fact that human beings are required to take care of the management. When there exists a special danger, in that instance, as well as in all other instances where danger threatens a community or a smaller body of persons extra precautions are taken to avoid anticipated possible trouble. It is quite natural, therefore, and if I should manage a filtration plant myself I should give the orders myself, that if a known epidemic exists there should be every reasonable precaution taken for special care to be exercised during that period.

"Q. Is there an artificial filtration plant in existence which removes 100 per cent. of the bacterial contents of the water?

"A. In the records which are published, and which I have seen, there are not infrequent ones where the bacteriological results give a removal of one hundred per cent. of the bacteria.

I remember seeing those in Europe, and I believe also within a few weeks ago in Philadelphia.

"Q. What is the cause in the variation in percentage of bacterial removal by these filtration plants?

"A. The cause is both to be sought in irregularity of construction and irregularity of operation. It is impracticable if not impossible to make a perfect construction, and it is likewise impracticable to demand of the average laborer or artisan or inspector or superintendent an absolute adherence to perfect conditions.

"Q. And as the degree of precaution in the management of the filtration plant increases so also the percentage of absolute removal of bacterial contents in the water is approached?

"A. Theoretically I will admit the truth of that position, but practically I should say that in the ordinary operation of filter works, particularly throughout Europe, where they have been managed for so many years, so far as we know typhoid fever germs have been entirely excluded. The remnant of cases that still appears in those cities is due to other causes than those of water pollution. It has been found in Europe, as well as in this country, that after the introduction of filter plants the typhoid fever rate has dropped generally to about one-fourth of the rate that previously existed. Some cities more and some cities less.

"Q. Those cities which you have just referred to have slow sand filtration plants, have they not?

"A. They have.

"Q. In the construction of a filtration plant is it not a fact that sanitary engineers take into consideration the extent of the infecting material discharged into a stream above in determining the character of the plant to be recommended?

"A. We do take that fact into consideration.

"Q. In recommending the construction of a filtration plant from the filtering of a water supply of a city which is taken from a running stream, sanitary engineers would recommend the use of larger quantities of sand, if it be that character of a

plant where the water of a river was subjected to the sewage of a city of 100,000 population than if such waters were subjected to the sewage of a city of one thousand population, would they not?

"A. The population would cut no figure in my mind. We would, under practical conditions, possibly recommend one system of filtration for a highly polluted water when we would be satisfied with another system of filtration in a very slightly polluted water.

"Q. Polluted or infected water?

"A. In this case it is either polluted or infected water.

"Q. What would be the difference in the character of the filter plants in the two cases mentioned in your last answer?

"A. My personal opinion, not speaking for the profession in general, when the water is highly polluted and infected, I should prefer the slow filters to the rapid filters for the reason that the chances for infection passing the slow filter would be very much reduced as compared with the chances of passing through a rapid filter. For the same reason that I would rather be on a slow-moving train than on a rapidly moving train if this train met with an accident. It is always possible in any public work to have something go amiss, although we try to make such works upon which not only a large expense but also the health of the people depends as nearly as practicable what we call fool proof.

"Q. The slow sand filtration plants are more expensive than the others, are they not?

"A. As a total expense generally not, sometimes less expensive, but sometimes more. The facts are these: The slow sand filter almost invariably costs more to build but less to operate than the rapid or mechanical filter. By adding the interest on the investment to the cost of operating expenses the two methods cost very nearly the same, but in some instances where sand in large quantities is not readily available, but must be brought from afar, and where the territory is not suitable for large, extensive beds; here the mechanical or rapid method is usually found more economical.

"Q. Assuming, Mr. Hering, that over the conditions that existed in 1900 at St. Louis, since that time a city containing a population of 160,000 has grown and been built on the Mississippi River immediately above the City of St. Louis, at the intake tower at the Chain of Rocks, would not conditions brought about by the discharge of the sewage from this city into the Mississippi River be considered in an item of using extra precaution, greater responsibility, more accurate and perfect means of operation in the construction or recommendation of the construction of a filter plant for that city than if such a city did not exist?

"A. I should say there would be a necessity for as careful a management as is practicable in such plant, and the filter plant should be so constructed and operated to allow of as careful an operation as is practicable.

"Q. Now, assuming that at all times the filtration plant thus constructed at the City of St. Louis did not remove all of the pathogenic bacteria, that the percentage of removal varied from day to day, week to week and month to month—assuming that the removal of pathogenic bacteria from the water ran in the same proportion; that is, that the percentage of the removal of such bacteria ranged at different rates from day to day, week to week and month to month. Under those assumptions is it not true that a greater number of pathogenic germs would pass through the filtration plant with a city of 160,000 population existing upon the Mississippi River immediately above the Chain of Rocks and the intake tower of the St. Louis Waterworks than there would in the event that such city was not so situated upon the Mississippi River, under conditions in both instances which existed at St. Louis prior to 1900?

"A. If your assumptions are correct I will be obliged to answer yes, but the conditions are such which would influence my recommendations as a sanitary engineer regarding the water supply of that city. I question very much whether I would put a filter plant immediately below so large a city, receiving the sewage of the city." (7006-7030.)

Professor W. P. Mason testified as follows:

"Q. Professor, have you had any experience in filter plants and in installation of filter systems for waters in rivers of this country? (6955.)

"A. Yes, sir, I have recommended a good many.

"Q. From your knowledge of conditions that obtain at St. Louis do you regard the water at St. Louis as a safe drinking water as it is at present treated with settling basins?

"A. I do not.

"Q. How should that water be treated in order to become a safe sanitary drinking water?

"A. A sedimentation should be supplemented by filtration. In this opinion of mine I entirely concur with what has been stated by Messrs. Hazen and Fuller in a report on the water supply for the City of St. Louis, dated 1902, in which Mr. Hazen says, after describing the method of filtration which he proposes, on page 77: 'I believe that the hygienic character of the purified water will be entirely satisfactory.'

"And on the same page: 'I believe that the raw water, although polluted far beyond the point where it should be used in its raw state, is very much less polluted than many or most of the river waters used by American cities. Purification will remove a very large percentage of the bacteria and the elements of danger in the raw water. So far as there is danger to health in the present water it will be reduced by filtration to an almost inappreciable amount.'

"Mr. George W. Fuller, in commenting upon Mr. Hazen's statements in this report, says on page 81 of the same report: 'With regard to this method of purification for the St. Louis water supply, it is my judgment that it will yield a water of satisfactory appearance and hygienic quality with proper construction and operation of the work, and that it is the best and most applicable method for the conditions existing at and near the Chain of Rocks.'

"Q. When was that report gotten out?

"A. 1902.

"Q. Do you concur in the views expressed by Mr. Fuller and Mr. Hazen as you have quoted them?

"A. I do.

"Q. In the installation of a plant for the filtration supply of the City of St. Louis, would the fact that sewage from Chicago entering the Chicago River and the Illinois River, thereafter commingling with the waters of the Missouri and Mississippi rivers, create any additional cost in the expense of the plant or in the operation of such a plant over conditions that would exist if the sewage of Chicago was eliminated?

"A. My opinion is that the addition of Chicago sewage via the Drainage Canal to the system of the Illinois River would not add any additional expenses to the purification of the Mississippi water by filtration at the Chain of Rocks. The installation and operation of the plant would not be greater in point of expenses by the addition of the Chicago sewage as it now is added to the system of the Illinois River.

"Q. Have you any acquaintanceship with any rivers more polluted than the waters in the Mississippi at the Chain of Rocks that have been successfully treated by a process of filtration?

"A. Yes, sir.

"Q. What are they?

"A. As an illustration I shall mention the Elbe River at Hamburg and the Hudson River below Troy, which latter supplies both Rensselaer and Albany." (6957.)

The testimony heretofore considered shows that the waters of the Illinois, Missouri and Mississippi rivers, before the opening of the Drainage Canal, as they united to form the Mississippi at the intake of the Chain of Rocks, were unfit in their raw state to be used without filtration for drinking and domestic purposes, even before 1900, the date of the opening of the Drainage Canal. It is therefore evident from the facts as above set forth and proven that the opening of the Drainage Canal did not create that necessity which had heretofore existed for purifying by filtration the water supply of St. Louis. No one who has testi-

fied in this case, save possibly Dr. Teichmann and Professor Keiser, has claimed that the water of the Missouri and Mississippi river prior to the opening of the Drainage Canal was a potable water, suitable for drinking purposes.

The evidence here set forth shows that the opening of the Drainage Canal has not created any added cost for installation or operation of a filter plant to meet the demands of St. Louis. The two witnesses who have had sufficient practical experience to justify them in passing an opinion upon this subject on the part of complainant are Mr. George W. Fuller and Mr. Allen Hazen, and Mr. Hazen, who worked out this problem for St. Louis and submitted his findings in a report, which was endorsed by Mr. Fuller, testified as above set forth, that the Drainage Canal would add no material cost to the expense of filtration. While Mr. Fuller testified to the contrary, endorsement of Hazen's official report upon filtration shows that his opinion was given without sufficient consideration of the problem concerning which he testified, and his cross-examination demonstrates the utter lack of preparation that he made as a basis for his testimony.

The opinion of Dr. H. E. Smith of Yale proves by his own cross-examination and admissions his lack of knowledge and experience in connection with the subject of filtration, and while Mr. Alvord professed large experience, his cross-examination revealed that his experience in the field of filtration was limited to the Lake Forest Mechanical Plant.

Arrayed against the position taken upon this subject by the witnesses for St. Louis, in which Mr. Hazen disagreed with them, is Mr. John W. Hill, who has charge of the installation and operation of the largest filtration plant that exists in this country, at Philadelphia. The opinion of Mr. Rudolph Hering, together with that of Professor Mason and Professor E. G. Smith of Beloit, taken in the light of their experience in installing and operating filtration plants, leaves no doubt whatever that the sewage of Chicago does not add any cost whatever to the problem of filtration for the water supply of St. Louis, and the

defendants contend that by a preponderance of the credible testimony in this case they have established the proposition that the opening of the Drainage Canal has in no manner increased that necessity which had heretofore existed for purifying by filtration the water supply of St. Louis, and that in the installation, operation and maintenance of a filtration plant sufficient to meet the requirements of St. Louis the opening of the Drainage Canal has created no added cost.

XII a

THE EVIDENCE IN THIS CASE ESTABLISHES THE FACT CONCLUSIVELY THAT THE SEWAGE DISCHARGED INTO THE MISSOURI RIVER AND THE MISSISSIPPI RIVER BY THE CITIES SITUATED WITHIN THE JURISDICTION OF COMPLAINANT IS SUFFICIENT OF ITSELF TO CONTAMINATE AND INFECT THE WATER SUPPLY OF THOSE CITIES IN MISSOURI OBTAINING THEIR SUPPLY OF WATER FROM THE MISSOURI AND MISSISSIPPI RIVERS, EXCLUSIVE OF ALL OTHER SOURCES OF CONTAMINATION OR POLLUTION ENTERING SAID STREAMS.

In support of the above proposition the defendants rely upon the testimony submitted in this case by Mr. Allen Hazen in his cross-examination, a part of which testimony is set out in full as follows:

"Mr. Todd: Did you examine the waters of the Missouri River? (2810.)

"A. Only as I saw it going into the Mississippi—wait a minute; that is not correct. I examined the plants of the waterworks at Kansas City, Kansas; Kansas City, Missouri; St. Joseph and Omaha to find out the character of the Missouri water and the methods which were necessary to treat it and the results which could be secured by those methods.

"Q. In your examination of the Omaha waterworks, did you ascertain whether the sewage from the City of Omaha and Council Bluffs entered into the Missouri River?

"A. I assumed that it did; I didn't ascertain it at that time.

"Q. Did you examine it as to whether the sewage of Kan-

sas City, Kansas, Kansas City, Missouri,—emptied into the Missouri River?

"A. I assume that it did. I examined some sewers in that case.

"Q. Did you examine as to whether Jefferson City emptied its sewage into the Missouri River?

"A. I assumed that all of the cities on the watershed sewered into the water courses.

"Q. And what effect did you assume this sewage to have upon the water—the quality of the water of the Missouri River before it emptied into the Mississippi?

"A. It injured its quality.

"Q. Did you consider it a safe and potable water?

"A. No, sir.

"Q. Do you consider it so now?

"A. No, sir.

"Q. A safe and potable water?

"A. No, sir.

"Q. If the Illinois River could be dammed at its mouth and a channel cut whereby it should empty below the intake tower of the City of St. Louis, would you consider the water of the Missouri and Mississippi which entered the intake tower at St. Louis a safe and potable drinking water?

"A. No, sir.

"Q. Assuming that a channel cut from the Illinois River should empty into the Ohio at Cairo, thus eliminating entirely the Illinois River water from the Mississippi between Cairo and Grafton, would you consider the water of the Mississippi at Cairo a safe and potable drinking water?

"A. No, sir.

"Q. Mr. Hazen, if you were to venture an opinion as to the character of the Mississippi River water above Cairo, would you consider that its character was made unwholesome and unpotable by the addition of the sewage discharged into the Mississippi River by the City of St. Louis and the cities in Missouri emptying their sewage into the Mississippi River, as well

as the cities on the Missouri emptying their sewage into the Missouri River?

"A. I think that the discharge renders the waters less wholesome and less potable. I cannot say that it renders it unwholesome and unpotable, because it may be that it would be unwholesome and unpotable without them.

"Q. In my hypothetical question I am assuming that the waters of the Illinois are eliminated by this supposed channel.

"A. Yes.

"Q. Now, consider the addition to the waters of the Missouri and the Mississippi, of the sewage discharged by the towns in Missouri into the Mississippi, as making that water an unsafe and unwholesome water for drinking purposes, without being treated?

"A. As I understand it, this question is substantially the same as the last one, and my answer would be the same.

"Q. What do you mean by the comparative term 'less wholesome' and 'less safe' as a sanitary engineer?

"A. I mean that they would produce, or might produce, more sickness and more deaths among those who used the water.

"Q. Assume that the waters of the Mississippi above its confluence with the Missouri and the Missouri above Kansas City, Missouri, were non-polluted streams, and assume that the sewage discharged into those rivers by the cities in Missouri, such as Kansas City, Missouri, Jefferson City, St. Charles, St. Louis and the other smaller towns that empty their sewage into those rivers, would you consider the water of the Mississippi River above Cairo a safe and potable water?

"A. I should not, offhand. It is a question that I have not studied in detail.

"Q. You know the population of Kansas City?

"A. Approximately.

"Q. You know the population of St. Louis?

"A. Yes.

"Q. You know approximately the population of the cities

in Missouri that empty their sewage into the Missouri and the Mississippi rivers, do you not?

"A. I have looked them up and listed them.

"Q. What further facts would you need to be put in possession of in order to form an opinion as to whether that water was a good, safe drinking water under the conditions presupposed in the previous question?

"A. A good safe drinking water is a relative term.

"Q. I would like to modify that question—a good safe drinking water in the language employed by sanitary experts?

"A. A good safe drinking water is a relative term. There are waters polluted so slightly or so remotely that notwithstanding the fact of pollution they are reasonably good waters. The amount of dilution and the period of time between the point of pollution and the point where the water is used are matters which have to be considered. In some cases I have studied these matters in detail and have formed judgments upon them. In this hypothetical question which you put to me I give you my impression, but I have not made computations concerning it, as I certainly should do if the question was presented to me for a professional opinion.

"Q. Would you consider the water of the Mississippi River above Cairo under the conditions existing in the hypothetical question, but with the additional information as to the rate of current and time of flow in the Missouri River, and the Mississippi River, a reasonably safe drinking water after it had received the addition of the sewage from these different cities in Missouri?

"A. I think not.

"Q. Will you explain to what extent it would not be a reasonably safe drinking water, and what do you mean by that term? (2814.)

"A. There are some waters that are so polluted that they cause death of more than one person from typhoid fever for each thousand people living, and seem to cause—although the evidence is less conclusive, but it is very good—and seem to

cause the death of four or five people altogether per annum, per thousand living, and water that does that is about as bad a water as is used anywhere in this country at this time. Waters that are less polluted than that produce smaller amounts of sickness and death. The question comes as to where to draw the line. It may be a question whether even almost the best waters that we have are absolutely free from suspicion of causing sickness and death, but when a water causes so little that it cannot be certainly traced, and measured, we class it as a good water, and the point at which that line is drawn is not and cannot be a sharp line. It is going down. A water that classed as good twenty years ago is classed as bad now, and a water that satisfies us today probably will not satisfy the most exacting people a generation hence.

"Q. Mr. Hazen, assume that in the southeast corner of the State of Missouri a company was about to establish a large city, and conditions existing along the Mississippi River above that point were such as are contained in the hypothetical question, and you should be selected as the sanitary engineer to look out for its water supply; knowing that the conditions such as I have assumed them in the hypothetical question, and before you could ascertain whether this water was going to kill anybody or not, what would you say as to whether the waters of the Mississippi under those conditions would be a safe drinking water for the future inhabitants of this supposed city, without being artificially treated?

"A. I think not.

"Q. That is, you would not consider that water a safe drinking water?

"A. No, sir.

"Q. Assume that the Illinois River should be diverted to Cairo in the manner I have indicated, and knowing all the conditions that obtain upon the upper watershed of the Mississippi and the Missouri rivers as they do today, and the water system in St. Louis as it now exists, would you consider that water a safe drinking water for the people of St. Louis, treated the way it is today?

"A. It is assuming that all the conditions upon the upper watershed are the same, except that the Drainage Canal is out.

"Q. Oh, no, the waters of the Illinois River?

"A. *I should not.*"

"Q. Then the cities bordering upon the Illinois River, and the conditions that obtained prior to January 17th, 1900, would not make the water supply of St. Louis a safe and usable water supply under existing conditions, in your judgment, would it?

"A. No, sir."

(See Vol. 3, pp. 2819 to 2816.)

The cities of St. Charles, Missouri, Kansas City, Missouri, St. Joseph, Missouri, St. Louis, Missouri, and Jefferson City, according to Dr. Ravold, discharged their sewage into the Missouri River. (863 to 872.)

Below St. Louis is the City of Cape Girardeau, and above, emptying into the Mississippi River, are the cities of Hannibal and Louisiana. Mr. Hazen's testimony upon this proposition, that the sewage from the cities in Missouri that empty their sewage into the Missouri and Mississippi rivers, exclusive of the sewage of any other locality, is sufficient to contaminate and to pollute the water supply of St. Louis, stands uncontradicted in the record in this case. And that fact, so well established by a witness called on behalf of complainant in this case, the defendants accept without question.

This fact demonstrates that there are cities within the jurisdiction of complainant, the State of Missouri, contributing infection and pollution to the Missouri and Mississippi rivers sufficient to make the waters of those streams, if they received pollution from no other source, unsafe waters for drinking purposes for the inhabitants of the State of Missouri living on the west bank of the Mississippi River. And defendants contend that the evidence above cited establishes the proposition above set forth.

XIII.

ACQUIESCENCE.

After the Sanitary District Act was passed by the Legislature in 1889 and the Sanitary District of Chicago was organized and the digging of the Drainage Canal begun, on the 3rd of September, 1902 (6620), the evidence in this case shows that the State of Missouri and the City of St. Louis had knowledge of that fact.

In the eighteenth annual report of the Health Commissioner of the City of St. Louis for the year ending March 31, 1895, there appears a report under the heading of "Federal Rivers Commission," which report is as follows:

"Federal Rivers Commission. A movement on the lines suggested in the report for last year was made in January by Honorable Richard Bartholdt, through the introduction into Congress of a bill which reads as follows:

"'A bill to appoint a commission for the investigation of the pollution of water supplies where such pollution affects or threatens to affect the sanitary condition of the people of more than one State.

"'Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, that a commission shall be appointed to investigate fully the subject of the pollution of rivers and other sources of water supply where the sanitary condition of the people of more than one State is affected or threatened to be affected by such pollution, this commission to consist of three members, to be appointed by the President, by and with the advice and consent of the Senate, whose compensation during the time when actually engaged in the performance of their duties under this act shall be ten dollars *per diem* each and reasonable expenses.

"'Sec. 2. That the commission shall meet in Washington, District of Columbia, within thirty days after the passage of this act, to consider the methods to be adopted in the investiga-

tion, and it shall have authority to be empowered to make use of the services of chemical, bacteriological and sanitary experts, and such persons as it may judge most competent, by reason of their special knowledge and experience, to afford it correct information on the subject of its inquiry, as well in formulating its methods as in carrying them into effect.

"'It shall meet thereafter from time to time at such places as it may consider best suited for the furtherance of this inquiry.

"'SEC. 3. That the commission shall report to Congress at its next session the progress made in the investigation undertaken under this act, and shall submit such suggestions as may seem desirable, with the view of remedying any unsanitary conditions that have been developed by its work.

"'SEC. 4. That the sum of ..... thousand dollars, or so much thereof as may be necessary, is hereby appropriated to pay the salaries and expenses of said commission and carry out the purposes of this act.'

"The General Assembly at its late session adopted a joint resolution asking the Missouri Congressmen to support this measure, and it is to be regretted that its introduction was delayed so long—the bill having died with the session—as, to judge by the expression of the sanitary opinion from the principal parts of the country, the time was ripe for legislation of this kind. Certainly no more important field is offered to progressive science and the thorough investigation as proposed of all streams touching more than one State would yield the data of the very highest practicable value to all concerned in the protection and preservation of the public health.

"The defilement of natural water courses has become one of the most conspicuous evils of modern civilization, and the harm and wrong are of such magnitude in this country that only the powers of the general government are adequate to deal with them properly. States and municipalities situated near the headwaters of potable streams are not so seriously threatened in this respect, but the great bulk of urban population is

found on the middle and lower reaches of such water course, hence the necessity for vigilant precaution.

"The invasion of this valley by a flood of filth naturally foreign to it, as is proposed by the construction and operation of the sewage canal leading from Chicago to a tributary of the Illinois River, will tend to enormously increase existing danger due to pollution of the upper Mississippi and from other sources and of the Missouri River from the sewage outflow of Kansas City, Leavenworth, St. Joseph, Omaha, etc.

"St. Louis is the focal point of all this drainage and must bear the brunt of the attack as best she may. No place of any considerable size below, drawing public supplies from the channel of the Mississippi River; therefore, the means of prevention and correction should be most diligently considered here now.

"At page 11 an asterisk at the bottom of the page is in words as follows:

"'This measure was drafted in December, 1894, by Major Charles Smart, Surgeon United States Army, upon the request of the Health Commissioner, later submitted to his Honor the Mayor, and by him forwarded to Washington.'

"On page 12 a footnote is indicated by an asterisk immediately after the word 'resolution' as heretofore quoted, and it is as follows:

"' Be it resolved by the General Assembly of the State of Missouri as follows: That our Senators and Representatives in Congress are requested to vote and urge the passage of the bill authorizing the national commission to investigate the pollution of streams, the waters of which flow through or adjacent to more than one State.' Approved March 9, 1893.

"Mr. TODD: Will you turn to page 25 of said eighteenth annual report and read what is there stated about a local commission?

"'A. That a local commission be formed under municipal authority to inquire fully into the quality of the water supply of St. Louis.'

"Mr. TODD: Will you turn to page 43 of the nineteenth

annual report of the Commissioner of Health of the City of St. Louis for 1895-6 and read what is stated there under 'Water Supply'?

"'A. Water Supply. The question as to the influence of the Chicago Drainage Canal as now in course of construction upon the water supply of St. Louis is one that should not be lost sight of. A bill creating a federal commission to investigate and suggest Congressional action of a remedial character is now before Congress. It is hoped that if such a law be enacted that selections for membership of the commission may be made that will recognize and protect the equitable demands of each locality.'"

The foregoing report shows conclusively that the State of Missouri, as well as the City of St. Louis, had knowledge that the Sanitary District had begun the construction of the Chicago Drainage Canal, and that this great public improvement was being constructed at a cost of a great many millions of dollars. (6679-6682.)

Notwithstanding the fact that this court, in passing upon the demurrer in this case, has considered the question of acquiescence, there are some observations upon this question of fact and law which the defendants desire to submit for the consideration of the court.

XIV.

SANITARY INCONSISTENCIES RECONCILED.

The evidence in this case on the part of some of complainant's witnesses has exhibited a great many inconsistencies of fact and of opinion which had to be reconciled in order to justify the conclusions expressed by them. The ingenuity displayed by some of those witnesses who advocated the cause of St. Louis is best illustrated by a reference to their individual testimony.

On account of the special emphasis placed by complainant upon the opinions expressed in this case and the great importance attached to such testimony, defendants desire to call the attention of the court briefly to certain statements made by complainant's witnesses in giving their evidence in this case.

The testimony in this case has shown the enormous volume of sewage and pollution which enters the Illinois River at Peoria, together with the large cities situated upon the tributaries of the Illinois emptying their sewage into these streams. Immediately below Peoria and across the river is situated the Town of Wesley.

Professor E. H. Keiser.

Defendants desire to call the attention of the court to the testimony of Professor Keiser, whose testimony is relied upon by complainant, in connection with that of Dr. Teichmann, to establish the chemical condition of the Illinois River before and since 1900. Professor Keiser testified that the chemical analysis shows that the pollution of the Mississippi River comes from the Illinois, and, from a sanitary standpoint, the water of the Mississippi River above the mouth of the Illinois is very similar to the waters of the Missouri, and, were it not for the inflow of the waters of the Illinois River, the Mississippi River, on both sides of the river, at the Chain of Rocks, would be of equal character; that it would be good drinking water on both sides. (1042.)

Professor Keiser, in drawing his comparison as to the con-

dition of the Illinois River at Peoria prior to 1900 with conditions since 1900, made use of Professor Long's tables of analyses as the same appear in the published reports of the Illinois State Board of Health. He stated:

"The samples which I analyzed and upon which I base my calculation were taken above Peoria. I don't know at what point with reference to Peoria the samples taken from the Illinois River by Professor Long were taken."

And from his tables and those of Professor Long he testified that the results would indicate an increase of pollution, of sewage, since 1900 at Peoria. (1076.)

On cross-examination these questions, among others, were asked him:

"Q. Now, I want to call your attention to the fact that that is the river below Peoria and not above Peoria at the Narrows, as you compared it with.

"A. Yes, I see that is Wesley.

"Q. That is after the river has been polluted by Peoria sewage?

"A. That is the analysis that is given. There is none given there above Peoria, *that is as near as we could come to it.*" (1116.) * * *

"Q. Well, is it fair to compare the waters at Wesley, that is, below the sewage of Peoria, with the waters above Peoria, which is above the sewage of that city, for the purpose of making any sort of a calculation or deduction?

"A. I assume that that made only a very slight difference, for the reason that the volume of sewage added by Peoria is comparatively small as compared with the bulk of sewage coming down the Drainage Canal.

"Q. Then you don't know that—you didn't know that Wesley was located below Peoria?

"A. I didn't know where it was, exactly. I didn't know whether the sewage of Peoria got into the river at Wesley. I thought it was considerably below, if anything. I didn't think it was right in the Town of Peoria." (1120, 1129.)

The foregoing testimony illustrates how important in an investigation of this kind, it is for a witness to be acquainted with the topography of the river concerning which he is testifying; to compare the Illinois River at the "Narrows" above Peoria with the Illinois River at Wesley City, immediately below the outfalls of the sewers of the city and the cattle sheds dumping the offal from those great industries there located, shows a serious lack of information in regard to a very important factor in connection with the sanitary problem of the lower Illinois River.

In his testimony Professor Keiser confessed that he had never traveled up the Illinois River with a view of determining the source of its water supply. (1080.) This fact, taken in connection with Professor Keiser's statement, "as we ascended the river we found the impurities increasing steadily as we went up the river, and I reasoned that if the impurities came slightly from the tributaries of the river the quantities of free ammonia and albuminoid ammonia and nitrates would be very constant all the way up the river and up through the tributaries, if the waters were homogeneous, they would show that on analysis, but we found as we ascended the Illinois River that there is a very great increase all the way up to Joliet, where the analyses showed the water to be diluted sewage" (1109), is certainly suggestive in view of the fact that he did not know that the sewage of Peoria entered the river above Wesley.

Again, Professor Keiser showed his lack of information in regard to the conditions that obtain upon the tributaries of the Illinois when this question was asked him:

"Q. Do you know, professor, as to whether or not there are any large cities or towns whose sewage outfalls are into the—in any of the tributaries of the Illinois River below where the canal, the Drainage Canal, joins the Desplaines River?

"A. I don't. I know of no large towns that run sewage into the tributaries of the Illinois." (1142.)

This answer is given, notwithstanding the fact that the cities of Springfield, Bloomington, Decatur, Elgin, Aurora and the

other cities heretofore described in the testimony are situated upon the tributaries of the Illinois.

Dr. W. C. Teichmann.

A review of the cross-examination of Doctor Teichmann, former City Chemist of St. Louis and witness for complainant, will disclose the fact that he was willing to testify as a bacteriologist, interpreting the bacterial data of Doctor Ravold, and from such data drawing conclusions as to the potability of the water of the Missouri and Mississippi rivers. Doctor Teichmann also testified that the Mississippi River at Grafton was a potable river and suitable for drinking purposes, but wouldn't venture an opinion as to whether the Mississippi River at the point where he made his examinations had purified itself of all the sewage emptying into it at points above. His cross-examination upon this point is set out at pages 1469-1486 of the printed record.

He also testified that the Missouri River was potable and had purified itself of all sewage entering the stream from points above. (1448-1494-1495.)

The Illinois River was able to purify itself of all sewage from its tributaries and the cities situated upon its banks prior to 1900, but the pollution that he found at the mouth of the river at the time that he made his chemical analyses of water selected above Grafton, prior to 1900, did not come from its tributaries or from Peoria, but came from the discharges of Chicago sewage through the Illinois and Michigan Canal (1635-1664), notwithstanding that he and other witnesses for complainant testified that the septic action in the Illinois and Michigan Canal had effectually destroyed the sewage prior to 1900.

Defendants, without desiring to set forth in greater detail the manifold contradiction of Dr. Teichmann, present to the court these observations which are sustained by the testimony of Doctor Teichmann, as reference to it will disclose. Defendants adopt this method of calling the attention of the court to the testimony of this witness without making any special application to

the facts involved in this case, but for the purpose of showing that the conclusions and opinions expressed in this case by the witness whose testimony has been above referred to, should be considered in connection with the foregoing facts.

Professor William T. Sedgwick.

Defendants desire to submit to the court, in addition to what has already been submitted in regard to Professor Keiser and Doctor Teichmann, statements made by Professor Sedgwick in connection with his testimony given in this case. This question was asked of Professor Sedgwick on cross-examination by Mr. Todd:

"Q. Assume, professor, that you occupied the position in St. Louis as a sanitary engineer and you were acquainted with all the conditions in regard to typhoid for the years 1897, '98 and '99 on the water shed as have been proven here in the evidence and as have been included in the different hypothetical questions, both the one put to you by Mr. Jeffries and the ones that I have presented to you, would you be able from your experience as a sanitarian as well as a scientific man to state what times, *under conditions existing in St. Louis as they did during those three years in regard to its water supply*, when it would be safe for the citizens to use the water that comes from the intake, and when it would not be safe, as explained in your previous answer?

"A. No, I should not be able to state the times when it would or would not be safe under the conditions assumed.

"Q. That being the case, would you, as a sanitarian, recommend to the citizens of St. Louis to use that water at any time during these periods, and recommend the same as being a safe drinking water?

"A. I should probably not have recommended it for drinking purposes or as a safe drinking water at any time during that period without treatment and purification, inasmuch as one would never know, could never know, assuming that typhoid bacilli once found access to the river above in these large num-

bers— could never know with any precision or certainty that these would have been effectually removed. Especially is this true with a watershed of this character upon which a rain, limited as to the area upon which it falls, might seriously affect the problem, and inasmuch, further, as the stirring of sediments by steamers or by fishermen might at any time convert what would otherwise be a well purified, flowing stream into one laden with danger." (2362-63.)

It will be observed that in the foregoing hypothetical question, it specially assumed "*under the conditions existing in St. Louis as they did during those three years, in regard to its water supply.*" The evidence in this case shows, and it is not disputed, that for *more* than five years before 1900 the settling basins were the only artificial means employed by the City of St. Louis for purifying its water supply; and Professor Sedgwick, as a sanitary engineer, knowing that condition and the conditions existing as to typhoid fever on the watershed above, stated that he should not be able to state the times when it would or would not be safe under the conditions assumed. Contrast his answer as sanitarian, in which capacity he answered the above question, with that of the epidemiologist, in which capacity he answers the following question:

"Mr. JEFFRIES: Assuming that the water supply of the City of St. Louis has been treated in the same manner since 1895, what, in your opinion, was the sanitary condition of the water supply of that city after treatment for the years 1895, 1896 and 1897, based on the typhoid fever death rate of the city for those years?

"A. My answer is that, judging partly by my knowledge of the methods of sedimentation employed, but chiefly by the typhoid fever death rate in St. Louis during those years, that the sanitary condition of the water supply as actually delivered to the citizens during those years was good.

Re-cross Examination by Mr. Todd.

"Q. What did you mean by the word 'good' in that sense?

"A. I meant that it must have been of such quality as to have probably produced little or no typhoid fever.

"Q. Is the word, in the sense you used it, safe and drinkable, the word 'good'?

"A. I should have considered it so in view of the facts.

"Q. And you took into consideration all of the facts in connection with typhoid fever for those years, did you?

"A. I did." (2417.)

It may be possible to view the character of the water supply of St. Louis for the period prior to January, 1900, from two distinct standpoints and express directly opposite opinions. These answers would indicate the versatility of a man testifying in a dual capacity of a sanitarian and epidemiologist, wherein, viewing the water supply based upon the typhoid conditions as they exist upon the watershed, he would not recommend it as being a safe drinking water, but as an epidemiologist, based on the typhoid fever death rate of the City of St. Louis for the years 1895, 1896 and 1897, the water supply as actually delivered to the citizens during those years would be denominated good, safe and drinkable water. While it is interesting to note the ability of the witness to draw different conclusions while testifying in different capacities, we are not satisfied that the real condition of the water as delivered to the consumers prior to 1900 is any different under one condition of facts as assumed in the first hypothetical question than it was under the other condition assumed in the latter, but it merely shows to the court the character of the testimony that complainant has offered in order to sustain its contentions.

In addition to the foregoing statements made by Professor Sedgwick, and taking into consideration the discussion already presented to the court in this brief upon the Detroit epidemic and typhoid fever in Lake Zurich, Switzerland, this question was asked of Professor Sedgwick:

"Q. Is there any positive knowledge, as distinguished from theory or deduction, as to the existence of typhoid germs in the sediment of running streams?

"A. Well, sir, I do not know any branch of knowledge more positive than rigid deductions, and I should say that the deductions drawn from the epidemics like that of Detroit and at Zurich are just as positive knowledge as we ever get in our ordinary scientific work in sanitary science, and that they were not dependent upon theory.

"Q. Do you know of a single instance in which the bacteria of typhoid fever have been found—discovered and identified in the sediment of running streams?

"A. I do not recall any such case." (2312.)

The foregoing questions and answers by Professor Sedgwick, when taken in connection with what the evidence in this case discloses the real conditions to have been in regard to the Detroit epidemic, and the alleged discovery of typhoid fever germs in the sediment of Lake Zurich, Switzerland, demonstrates much better than it could possibly be characterized by defendants the method resorted to by him in order to reconcile an inconsistency. No scientific demonstration that typhoid germs live for a long time in the sediment of the Illinois River has been produced. The fact that the cause of the Detroit epidemic is more of a myth than a reality, and that the typhoid germs that were alleged to have been found in the sediment of Lake Zurich are not accepted as such by leading sanitarians today, shows how readily illustrations were accepted in order to illustrate a theory not based upon scientific truth.

And, again, in order to illustrate how Professor Sedgwick reasoned in order to arrive at his far-reaching conclusions, it is only necessary to quote the following extract from his testimony:

"I might even go further, and say that as between wells taken in a general and large way, and including a certain number of polluted wells, and a city water supply not above suspicion, it is by no means clear, in my mind, that the use of such

wells would at any time increase the typhoid fever rate over and above the use of a water supply which was not entirely pure. I, therefore, exclude altogether the wells of the City of St. Louis as producing any important part of the increase in typhoid fever since January 1, 1900.

"Q. Do you consider that the information which you have is sufficient to establish your conclusions beyond a reasonable doubt?

"A. I do.

"Q. How many wells in the City of St. Louis have you investigated personally that outhouses drain into?

"A. None.

"Q. How many outhouses in the neighborhood of these wells within these three years have received the excrement of typhoid patients?

"A. I do not know.

"Q. How many people living in the houses where these wells are located and drinking the well water have contracted typhoid fever, from that, if you know?

"A. I have no means of knowing.

"Q. In the absence of knowledge upon these three propositions do you claim, as an expert sanitarian, that your conclusions in answer to my former questions were established beyond a reasonable doubt?

"A. I do." (2342-2343.)

From the foregoing extracts taken from the testimony of Professor Sedgwick, it appears how easy it is for an expert witness employing that method of reasoning to establish a fact beyond "a reasonable doubt," when there is an entire lack of information in regard to the premises from which the conclusion is drawn; and defendants submit that it is difficult, indeed, by any process of reasoning which ordinary mortals employ, to arrive at like conclusions based upon the same lack of important information, as is indicated in the testimony of Professor Sedgwick, as above cited.

Mr. John W. Alvord,

Who was called in rebuttal by the complainant, and who gave as his serious opinion that he was accustomed "for some years past to consider that the life of the typhoid bacillus would be from sixty to ninety days under favorable environments" (7771), and who qualified as an epidemiologist, and as such gave some far-reaching opinions in this case upon the questions involved in this controversy, on cross-examination testified as follows:

"Q. What experiments have you conducted upon the longevity of the typhoid germ, as a bacteriologist?

"A. None whatever.

"Q. Have you ever separated the typhoid germ in the laboratory from the excreta of typhoid patients?

"A. I have not.

"Q. Are you sufficient of a bacteriologist to do so?

"A. I am not.

"Q. Have you ever made any experiments of your own upon the longevity of the typhoid germ in sewage?

"A. I have not.

"Q. Have you made any experiments of your own upon the longevity of the typhoid fever germs in sterilized water, in the lake water, in the water of the Drainage Canal or the waters of the Illinois River?

"A. I have not." (7802.)

If the value of Mr. Alvord's opinion as to the longevity of the typhoid germ and his conclusions based thereon are to be measured by his actual, personal knowledge of the life history of the typhoid organism, his conclusions cannot be held to have much weight in deciding the issues of this case. Taking into consideration his lack of knowledge of the typhoid organisms in connection with his actual experience in the construction of filter plants, referred to in this brief in another place, together with the ease with which he testified in regard to the manner of disposing of Chicago sewage and the cost of doing it, with his explanation given on cross-examination showing his actual

information upon an engineering proposition of such magnitude and importance, it will be seen how little personal knowledge and experience some people require in order to qualify as an expert in a lawsuit.

Mr. Gardner S. Williams.

Whose testimony has been referred to in other parts of this brief, and who is the author of the so-called Detroit Epidemic, testified that among those germs which have been found to have a considerable length of existence in water are the germs of diphtheria, tetanus and anthrax. He stands as the only witness in this case who contends that diphtheria is a water borne disease, and his statements in regard to anthrax and the danger that St. Louis might experience by reason of the opening of the Drainage Canal are indeed very interesting. "Should anthrax be present among cattle which are daily slaughtered in the Chicago Stock Yards and from them be transmitted by the discharges from the nostrils, mouths or bowels of those cattle, into the sewers of Chicago, there would be no question that the germs of anthrax might easily find a lodging in the people of Missouri with extremely fatal results. * * * Should the sewage of Chicago become infected with germs of anthrax, and should those germs be transmitted, as they undoubtedly would be, into the waters of the Mississippi, if the Drainage Canal continues to discharge the sewage of Chicago into the Desplaines and Illinois rivers, at such times there would be great danger of the occurrence of an epidemic of anthrax, not only among the human inhabitants of the State of Missouri, but also among the lower animals using the water." (2469.)

On cross-examination he was asked:

"Q. Now, in regard to this anthrax occurring in Chicago, did you ever hear of a case of anthrax in the City of Chicago?

"A. I don't know that I have. No, I am free to say that I have not heard of a case coming from the City of Chicago. (2579.)

"Q. When you look into the future do you expect to see an anthrax epidemic in Missouri?

"A. I should not be surprised understanding that there has been an epidemic of it in Missouri in the past two years?

"Q. How long ago was it?

"A. I could not say exactly, a matter of a few years.

"Q. As much as five years?

"A. It may have been. I am not certain. My impression is it was two or three years ago. It may have been four or five.

"Q. Well, if it was prevalent here prior to the opening of the Drainage Canal and the germ of anthrax is indestructible, would you, as a scientist who dips into the future, attribute a subsequent epidemic to any contagion that might come from Chicago?

"A. *I shouldn't be inclined to attribute an epidemic of anthrax to Chicago upon its first appearance, but, knowing the intimate relations which exist between Missouri, or between Chicago and St. Louis, I could readily conceive that the anthrax beginning in Missouri might travel to Chicago, infect the Chicago sewage and come back to Missouri with redoubled force as a result, and that such is quite probable, and that the existence of such a possibility is an added menace to the health of the people of the State of Missouri.*" (7582.)

Can anything be found in the domain of expert testimony that can excel in ingenious originality this explanation showing how Chicago sewage infected from a case of anthrax, sent to Chicago from Missouri, becomes an added menace to the health of the people of the State of Missouri?

Defendants contend that it is unnecessary to comment upon expert testimony of the character as above set forth.

Reference is made to the testimony hereinabove quoted for the purpose of calling the attention of the court to some of the novel positions taken by some of the experts who have testified in this case for complainant, and in view of the great importance attached to their testimony in complainant's brief, these facts, defendants contend, are worthy to be taken into consider-

ation by the court in deciding the weight and value to be given to the opinions expressed by the aforementioned witnesses.

Mr. Allen Hazen,

Who testified in this case on the part of complainant, has introduced a new method of arriving at the increase of typhoid fever, based upon statistics, as is evidenced by the following extract from his testimony:

"Q. Now, assuming, Mr. Hazen, that in the City of St. Louis the true situation was in 1900 that out of the total number of typhoid fever cases—there were 1,213—168 people died; in 1901 there were 1,101 cases and 198 people died; for those two years would you say that typhoid fever in the City of St. Louis was on the increase or on the decrease?

"A. I should say it was on the increase.

"Q. In other words, the more people that die and the less number of cases would be indicative of an increase in typhoid fever, and if few people died and more cases prevailed it would be on the decrease?

"A. That would, in general, be my conclusion, but I think a full, accurate statement of that kind would include data upon both points.

"Q. Do you reason that way, Mr. Hazen, upon any other line of thought or business with which you have any connection?

"A. Reason in what way?

"Q. The same kind of reasoning that you apply in answer to my last question about the increase or decrease of typhoid fever?

"A. I endeavor to use my best reasoning power on all the problems that I consider." (2843.)

The foregoing testimony, when properly considered, may be a tribute to the method employed by Mr. Hazen in drawing his conclusions, but from the standpoint of defendants we must contend that he has not convinced us that the number of people who die, and not the number of cases, is the true index of typhoid conditions existing in a given city.

When the testimony hereinbefore quoted as given by the witnesses for complainant, in connection with their other testimony, is considered merely in the light of reason and of human experience, it seems almost impossible that the positions taken by these different experts are such as they would endorse in the seclusion of their laboratories and studies; and, were it not for the immense interests involved in this litigation, and the effect that such testimony might have in deciding the pending issues, the defendants would prefer to have it remain undisturbed in the silent archives of this case, rather than exhibit it to the attention of the court.

XV.

ASSIGNMENT OF POINTS OF FACT.

(1)

That the water of the Illinois River at Grafton since the opening of the Drainage Canal, as disclosed by chemical and bacterial surveys covering a long period of time, is, if anything, in a better sanitary condition since the opening of the Drainage Canal than it was prior thereto.

(2)

That the Illinois River at its mouth, from a sanitary standpoint, based upon chemical and bacterial analyses, is less polluted and less dangerous to health than is either the Missouri River or the Mississippi River, and the Illinois River, emptying into the Mississippi and Missouri rivers, is contaminated and polluted by these two rivers, instead of contaminating and polluting the combined waters of the Mississippi and Missouri rivers.

(3)

That since the opening of the Drainage Canal the water of the Illinois River has been improved for agricultural, piscatorial and manufacturing purposes by virtue of its dilution with the pure waters of Lake Michigan.

(4)

That typhoid conditions existing in the City of St. Louis, as evidenced by its public health statistics, cannot be charged, in whole or in part, to the Sanitary District of Chicago.

(5)

That the water supply of St. Louis is polluted and infected defendants do not deny; but they assert that the infected mate-

rial bringing about this condition is derived, not from Chicago, but from towns, villages and rural communities much nearer, in point of time, to the St. Louis intake at the Chain of Rocks.

(6)

That the evidence in this case establishes affirmatively, beyond all question, that the number of deaths under the heading "Typhoid Fever" in the published reports of the Board of Health of the City of St. Louis, and as employed and used by the complainant in this controversy to establish their case that typhoid fever has increased in the City of St. Louis since January, 1900, do not correctly show the typhoid conditions existing in the City of St. Louis since 1900, or the typhoid conditions that obtained in St. Louis prior to 1900, for the reason that in the published reports of the Board of Health of the City of St. Louis there appears a column of nondescript fevers characterized under the names of intermittent, remittent, typho-malaria, congestive and simple continued fevers, and under this heading there appears a definite number of deaths attributed to these various fevers; and the evidence in this case establishes, beyond any question, that these nondescript fevers are, in reality, mainly typhoid fever, and should have been classified under the heading "Typhoid Fever," and not classified separately as distinct types of fever, and that only by uniting the deaths reported under the head of Typho-malaria, etc., with those reported under Typhoid Fever can an approximate judgment of the true typhoid fever mortality in St. Louis be obtained; that when properly compiled and analyzed the typhoid fever statistics of the City of St. Louis, as shown in its published Board of Health reports, do not disclose any real increase of typhoid fever, or, at most, a doubtful or a halting one, such as might be expected in a World's Fair city, with a considerable influx of population that admits of continuous sources of infection. No explosive outbursts of typhoid fever, such as characterizes water borne epidemics, followed the opening of the Drainage Canal.

(7)

That the evidence in this case establishes affirmatively, by a preponderance of the testimony, the following propositions:

(a) The typhoid germ entering the sewers of Chicago will not survive the journey to the intake tower of the City of St. Louis in a virulent condition and be able to cause typhoid fever among the inhabitants of the City of St. Louis.

(b) Typhoid germs from Chicago will not make the journey to the Mississippi River and become a danger and a menace to the inhabitants of the State of Missouri taking their water supply from the waters of the Mississippi River.

(c) That the opening of the Drainage Canal is not a danger and a menace, present or impending, to the inhabitants of the State of Missouri taking their water supply from the Mississippi River.

(d) That a typhoid germ leaving the sewers of Chicago, by way of the Drainage Canal, will have perished long before Grafton is reached on the Illinois River.

(8)

That the necessity of purifying by filtration or other means the water supply of the City of St. Louis, as the same is derived from the Mississippi River, existed as far back as 1866, and was so recognized by the authorities in St. Louis, and has continued to be so recognized up to the present time.

(9)

That the opening of the Drainage Canal has in no manner increased the necessity which has heretofore existed for purifying by filtration the water supply of St. Louis, and in the installation, operation and maintenance of a filtering plant sufficient to meet the requirements of St. Louis the opening of the Drainage Canal has created no added cost.

(10)

That the evidence in this case establishes the fact conclusively that the sewage discharged into the Missouri and the Mississippi rivers by the cities situated within the jurisdiction of complainant is sufficient of itself to contaminate and infect the water supply of those cities in Missouri obtaining their water supply from the Missouri and Mississippi rivers, exclusive of all other sources of contamination or pollution entering said stream.

(11)

There is no testimony offered in evidence in this case showing that any damage has been sustained by complainant, the State of Missouri, by virtue of the opening of the Drainage Canal, much less any that can be measured in dollars and cents.

PART TWO.

XVI.

PROPOSITIONS OF LAW.

I.

That in the prosecution of the work of the Chicago Drainage Canal by the defendant, the Sanitary District of Chicago, at an expenditure of over $42,500,000, the complainant had knowledge of this great public improvement and has stood by in silence and acquiesced impliedly in its construction.

II.

That a court of equity will refuse to grant an injunction when it appears that greater injury and inconvenience will be caused to the defendants by granting an injunction than will be caused to the complainant by refusing it.

III.

That a court of equity will not grant an injunction to restrain a party from committing a nuisance when the evidence shows that the party complaining is guilty of contributing to the nuisance of which he complains. If the granting of an injunction will not relieve him from the consequences of his own act, the injunction will not issue. If the complainant contributes to the conditions which it claims in its bill of complaint will injure it as a State, it cannot obtain equitable relief.

IV.

That the evidence of E. E. Lockridge, one of the complainants' witnesses, who testified to the contents of the public records of the mortuary office of the City of St. Louis from personal

examinations, is objectionable for the reason that the record itself or a duly certified copy of it is the best evidence, and no legal foundation was laid for the introduction of secondary evidence to prove its contents. The contents of a public record cannot be proved by parole evidence and therefore his testimony should be excluded by the court.

V.

That an injunction to restrain a nuisance will issue only in cases where the fact of nuisance is made out upon determinate and satisfactory evidence; that if the evidence be conflicting, and the injury be doubtful, that conflict and doubt will be a ground for withholding the injunction; and that where interposition by injunction is sought to restrain that which is apprehended will create a nuisance of which its complainant may complain, the proof must show such a state of facts as will manifest the danger to be real and immediate.

The points of fact as hereinabove set forth have been fully discussed in the preceding part of this brief under each of the foregoing headings, and defendants desire to submit to the court a discussion of the law which they contend is involved in this controversy. These propositions will be discussed under their respective heads.

XVII.

I.

THAT IN THE PROSECUTION OF THE WORK OF THE CHICAGO DRAINAGE CANAL BY THE DEFENDANT, THE SANITARY DISTRICT OF CHICAGO, AT AN EXPENDITURE OF OVER $42,500,000, THE COMPLAINANT HAD KNOWLEDGE OF THIS GREAT PUBLIC IMPROVEMENT AND HAS STOOD BY IN SILENCE AND ACQUIESCED IMPLIEDLY IN ITS CONSTRUCTION.

The court, in passing on the demurrer of defendants to the complainant's bill of complaint herein say: "It is finally contended that, if the bill was not prematurely filed, then it was filed too late; that by standing by for so long a period, the complainant was guilty of such laches that a court of equity will not grant relief.

The inconsistency between these contentions is manifest, and, on consideration, we are of opinion that the suggestion that the complainant's remedy has been lost by delay is not founded in fact or reason."

This opinion was based upon the facts as they appeared from the face of the pleadings only, and it goes only to the extent of holding that the court cannot say from the facts as they so appear that, as a matter of law, the complainant was guilty of laches in failing to bring its suit in apt time.

Upon a full hearing of the evidence in the case it will still be a controlling question for the court to decide whether or not the complainant has been guilty of such laches and acquiescence as will defeat its right to relief in a court of equity.

A court of equity takes into consideration the rights and interests of both complainant and defendant as shown by the evidence, and will endeavor to so adjust matters that neither one suffers through the fault, negligence or tardiness of the other.

If the evidence discloses that the complainant knew of the

work being done by the defendants, almost from its inception, and was aware of its ultimate purpose, its magnitude and the immense outlay of public money being expended upon it, and gave no sign of disapproval, or of a purpose to finally put a stop to the use of the canal when completed, surely the court will consider these facts, and if not holding them to be a bar to complainant's obtaining equitable relief, will at least take them into consideration in fixing the remedy to be applied in the case.

Laches and acquiescence have always been given great weight by the Supreme Court of the United States, and all other courts exercising equitable powers, as elements to be considered in passing upon the merits of cases in equity. Especially is this the rule where the complainant stands by and allows large sums of money and an immense amount of time to be spent upon a work without protest or notice of an intention to object to it.

We have, therefore, in addition to the cases cited by counsel in the briefs presented to the court on demurrer, selected the following cases which seem to express the opinion of the courts on the question under a similar state of facts.

Wood, in his treatise on the Law of Nuisances, lays down the following: "A party may, by laches, deprive himself of an equitable remedy against a nuisance. Thus, if a party sleeps on his right and allows a nuisance to go on without remonstrance, or rather without taking measures, either by suit at law or in equity, to protect his rights, *and allows the party to go on making large expenditures about the business which constitutes the nuisance*, he will be regarded as guilty of such laches as to deprive him of equitable relief, particularly until the right has first been settled at law, *and where the delay is also coupled with an acquiescence he will be deprived of all equitable relief*, and may be placed in a position where the court will enjoin him from proceeding against the nuisance at law, or even to prevent the recovery of a judgment obtained therefor in a court of law.

"A party affected by a nuisance cannot sleep upon his rights and delay and temporize and excuse himself upon the ground that he expected some one else affected by the nuisance to move in the matter. It is his business to protect and look out for his own rights. * * * If the thing or erection is of itself, or in the use to which it is to be devoted, in its nature a nuisance, assent thereto, or active acquiescence therein, is such an acquiescence as will deprive a party of an equitable remedy, and after the erection is completed, and by its use become a nuisance, if the party without taking measures to stop the nuisance by suit allows the owner to go on making large additions thereto, or expend money upon the same in its repair, this will operate as an equitable estoppel which will warrant a court of equity in restraining proceedings at law for damages arising from the nuisance. * * *

"A party must not sleep upon his rights when such delay operates as an acquiescence in a wrongful act injurious to him, *particularly when by reason of such delay the other party goes on and expends money in his erections about his business and is thus subjected to loss* that proper and timely action on the part of the plaintiff would have prevented. If he does, when he goes into a court of equity for relief he will be told that he has come too late and is without equitable relief."

Wood on Nuisances, Vol 2, Sections 804, 805 and 806.

Gould, in his work on Waters, says: "Acquiescence or laches by the party injured may bar his right to the interference of equity even if the legal right is clearly made out, but a greater degree of consent or delay is necessary than in the case of the interlocutory motion. *Any contribution by the plaintiff to the acts producing the injury, a fortiori, bars his right to an injunction.* Such acquiescence is not only a bar to the injured party's right to an injunction, but may become a ground for an injunction against any proceedings, either at law or in equity.

"Neglect on the part of the public may create such an equitable estoppel as to lead the courts of equity to decline to exert the extraordinary remedy of an injunction in its behalf. Such neglect is not in any sense a bar of the right of the public, but is a circumstance to be considered by the court in connection with the other circumstances of the case in determining whether the conduct of the plaintiff justifies an interference by equity. Thus, in *Attorney General* v. *Johnson*, which was a case of purpresture, Lord Eldon said, 'If the king's subjects have permitted the erection of a building which they were aware would when completed be a nuisance without promptly applying to the court to prevent it, the court would not consider them entitled to the extraordinary assistance of a court of equity, but leave them to their legal remedy.'

"In *Attorney General* v. *Bradford Canal*, Vice-Chancellor Wood expressed a similar opinion. This was the ratio decidendi so far as the public right was concerned in the case of *Attorney General* v. *Sheffield Gas Consumers' Co.*, where Turner, L. J., said: 'That delay will affect the Attorney General as much as a private individual, I am not prepared to say; but in my opinion it is a circumstance to be considered in determining the question whether this court shall interfere, although the application to the court be on behalf of the Attorney General, but I ground myself in that opinion upon what fell from Lord Eldon in the case of *Attorney General* v. *Johnson*.'"

Gould on Waters, Sections 530, 533.

IT IS THE WELL ESTABLISHED DOCTRINE OF THE SUPREME COURT OF THE UNITED STATES THAT LACHES ON THE PART OF THE COMPLAINANT IS A BAR TO THE GRANTING OF EQUITABLE RELIEF. THIS IS ESPECIALLY SO WHERE THE LACK OF DILIGENCE ON THE PART OF THE COMPLAINANT HAS LED THE DEFENDANT TO PLACE HIMSELF IN A POSITION FROM WHICH HE CANNOT ESCAPE OR RECEDE WITHOUT GREAT LOSS AND INCONVENIENCE.

THE QUESTION OF LACHES DOES NOT DEPEND AS DOES THE

STATUTE OF LIMITATIONS UPON THE FACT, THAT A CERTAIN DEFINITE TIME HAS ELAPSED SINCE THE CAUSE OF ACTION ACCRUED, BUT WHETHER UNDER ALL THE CIRCUMSTANCES OF THE PARTICULAR CASE PLAINTIFF IS CHARGEABLE WITH A WANT OF DUE DILIGENCE IN FAILING TO INSTITUTE PROCEEDINGS BEFORE HE DID.

McKnight v. *Taylor*, 1 How., 168.
Badger v. *Badger*, 2 Wall., 87.
Twin Lake Oil Co. v. *Marbury*, 91 U. S., 587.
Hayward v. *Elliot National Bank*, 96 U. S., 611.
Harwood v. *Cincinnati & C. Air Line Co.*, 17 Wall, 79.
Apeidel v. *Henrici*, 120 U. S., 377.
Galiher v. *Cadwell*, 145 U. S., 368.
Hammond v. *Hopkins*, 143 U. S., 224.
Willard v. *Wood*, 164 U. S., 502.
Sullivan v. *Portland & K. R. Co.*, 94 U. S., 806.
Lansdale v. *Smith*, 106 U. S., 391.
Lane & B. Co. v. *Locke*, 150 U. S., 193.
Mackall v. *Casilear*, 137 U. S., 556.
Whitney v. *Fox*, 166 U. S., 637.
Gildersleeve v. *New Mexico Min. Co.*, 161 U. S., 573.
Ware v. *Galveston City Co.*, 146 U. S., 102.
Foster v. *Mansfield C. & L. M. R. Co.*, 146 U. S., 88.
Hoyt v. *Latham*, 143 U. S., 553.
Hanner v. *Moulton*, 138 U. S., 486.
Richards v. *Mackall*, 124 U. S., 183.
Roberts v. *Northern P. R. Co.*, 158 U. S., 1.

"To let in the defense that the claim is stale, and that the bill cannot, therefore, be supported, it is not necessary that a foundation shall be laid by any averment in the answer of the defendants. If the case, as it appears at the hearing, is liable to the objection by reason of the laches of the complainants, the court will, upon the ground be passive, and refuse relief. Every case is governed chiefly by its own circumstances; sometimes

the analogy of the Statute of Limitations is applied; sometimes a longer period than that prescribe[illegible]e statute is required; in some cases a shorter time is sufficient; and sometimes the rule is applied where there is no statutable bar. It is competent for the court to apply the inherent principles of its own system of jurisprudence, and to decide accordingly. (Wilson v. *Anthony*, 19 Barber (Ark.), 16; *Taylor* v. *Adams*, 14 *id.*, 62; *Johnson* v. *Johnson*, 5 Ala., 90; *Ferson* v. *Sanger*, 2 Ware, 256; *Fisher* v. *Boody*, 1 Curtis, 219; *Cholmondy* v. *Clinton*, 2 Jac. & Walk., 141; 2 Story's Eq., Section 1520a.)

"A court of equity, which is never active in giving relief against conscience or public convenience, has always refused its aid to stale demands where a party has slept upon his rights and acquiesced for a great length of time. Nothing can call forth this court into activity but conscience, good faith and reasonable diligence. Where these are wanting the court is passive, and does nothing. Laches and neglect are always discountenanced, and, therefore, from the beginning of this jurisdiction there was always a limitation to suits in this court." (*Smith* v. *Clay*, Ambler, 645.)

Sullivan v. *Portland R. R. Co.*, 94 U. S., 806 and 811.

"No rule of law is better settled than that a court of equity will not aid a party whose application is destitute of conscience, good faith and reasonable diligence, but will discourage stale demands, for the peace of society, by refusing to interfere where there have been gross laches in prosecuting rights, or where long acquiescence in the assertion of adverse rights has occurred. * * * Each case must necessarily be governed by its own circumstances, since, though the lapse of a few years may be sufficient to defeat the action in one case, a longer period may be held requisite in another, dependent upon the situation of the parties, the extent of their knowledge or means of information, great change in values, the want of probable grounds for the imputation of intentional fraud, the destruction

of specific testimony, the absence of any reasonable impediment or hindrance to the assertion of the alleged rights, and the like. (*March* v. *Whitmore*, 21 Wall., 178; *Lansdale* v. *Smith*, 106 U. S., 391; *Norris* v. *Haggin*, 136 U. S., 386; *Mackall* v. *Casilear*, 137 U. S., 556; *Hanner* v. *Moulton*, 138 U. S., 486.)"

Hammond v. *Hopkins*, 143 U. S., 224 and 250.

"Nothing can call forth"—a court of equity—"into activity but conscience, good faith, and reasonable diligence. Where these are wanting, the court is passive, and does nothing. Laches and neglect are always discountenanced, and, therefore, from the beginning of this jurisdiction there was always a limitation of suits in this court. (*Smith* v. *Clay*, Amb., 645. See, also, Story, Eq. Jur., Sec. 1520a; 94 U. S., *supra; Sample* v. *Barnes*, 14 How., 70; *Walker et al.* v. *Robbins et al., Id.*, 584; *Creath's Administrator* v. *Simms*, 5 *id.*, 192; *Bateman* v. *Willoe*, 622; *Callaway* v. *Alexander*, 8 Leigh (Va.), 114; *Powell* v. *Stewart*, 17 Ala., 719; *Riddle* v. *Barker*, 13 Cal., 295.)"

Brown v. *County of Buena Vista*, 95 U. S., 157, 160, 161.

In the case of *Roberts* v. *Northern Pacific Railroad Co.*, 158 U. S., p. 1, the court said on page 11:

"So, too, it has been frequently held that if a land owner, knowing that a railroad company has entered upon his land and is engaged in constructing its road without having complied with the statute, requiring either payment by agreement or proceedings to condemn, remains inactive and permits them to *go on and expend large sums in the work*, he will be estopped from maintaining either trespass or ejectment for the entry, and *will be regarded as having acquiesced therein*, and be restricted to a suit for damages. (*Lexington & Ohio Railroad* v. *Ormsby*, 7 Dana, 276; *Harlow* v. *Marquette, &c., Railroad*, 41 Michigan, 336; *Cairo & Fulton Railroad* v. *Turner*, 31 Arkansas, 494; *Pettibone* v. *La Crosse and Milwaukee Railroad*, 14 Wisconsin, 443; *Chicago & Alton Railroad* v. *Goodwin*, 111 Illinois, 273.)"

Roberts v. *Northern Pacific Railroad Co.*, 158 U. S. Rep., 1-11.

In the case of *Gallaher* v. *Cadwell*, 145 U. S., p. 368, the court discusses the question of laches very fully and cites the leading cases in the United States Supreme Court, and says:

"But it is unnecessary to multiply cases. They all proceed upon the theory that laches is not like limitation, a mere matter of time, but principally a question of the inequity of permitting the claim to be enforced—an inequity founded upon some change in the condition or relations of the property or the parties."

Gallaher v. *Cadwell*, 145 U. S. Rep., 368.

In the case of *Johnston* v. *Standard Mining Co.*, 148 U. S., 360. the Court says:

"Under such circumstances, *where property has been developed by the courage and energy at the expense of the defendants*, courts will look with disfavor upon the claims of *those who have lain idle* while awaiting the results of this development, and will require not only clear proof of fraud, *but prompt assertion of plaintiff's rights.* (*Felix* v. *Patrick*, 145 U. S., 317, 334; *Hoyt* v. *Latham*, 143 U. S., 553, 567; *Hammond* v. *Hopkins*, 143 U. S., 224; *Great West Mining Co.* v. *Woodmas Mining Co.*, 14 Colorado, 90.)"

Johnston v. *Standard Mining Co.*, 148 U. S. Rep., 360.

Barnard v. *Shirley:*

"It is a question, also, whether appellee, having stood by and assented to and acquiesced in the expenditure of said sum of ten thousand dollars in the erection of said bath house, is not now estopped from seeking to enjoin continuation of its use. For over a year before this she had also acquiesced in the flowing of the artesian

water into the stream, and now she could hardly be ignorant of the purpose for which the sanitarium was to be used. This court has held that, under certain circumstances, by remaining silent, and allowing acts to be done and expense to be incurred, persons may lose their remedy by injunction, and be compelled to assert their rights at law. *Logansport* v. *Uhl*, 99 Ind., 531, 49 Am. Rep., 109, and authorities there cited. In New Jersey it was held that if a person "has given his consent, either expressly or impliedly, to the erection of expensive works, he cannot afterwards enjoin their operation, though they prove more annoying or injurious than he anticipated. *Hulms* v. *Shreve*, 4 N. J. Eq., 116. We think the facts stated in the second paragraph of the answer sufficient."

Barnard v. *Shirley*, 24 L. R. A., 568-74-5.

EQUITY WILL NOT INTERFERE TO AID A PLAINTIFF WHO HAS STOOD BY IN SILENCE AND HAS ACQUIESCED IMPLIEDLY IN THE EXPENDITURE OF LARGE SUMS OF MONEY BY THE DEFENDANT IN THE BELIEF THAT HIS WORK WAS RIGHTFUL AND WOULD NEVER BE INTERFERED WITH.

High on Injunctions, Sec. 618, 643, 884 and 88d.
Wendell v. *Van Rensselaer*, 1 Johns, Chan. Rep., 343.
Dougrey v. *Topping & Holme*, 4 Paige's Chan. Rep., 93.
Town v. *Needham & Harvey*, 3 Paige's Chan. Rep., 546.
Blanchard v. *Doering*, 23 Wis., 200.
Sprague v. *Steere*, 1 R. I., 247.
Patterson v. *Hewitt*, 55 L. R. A., 658-662-670.
Swain v. *Seamens*, 76 U. S., 254-273-274.
Pomeroy Eq. Jur., Vol. 2, p. 2, Secs. 816 to 821, inclusive.
Niven v. *Belknap*, 2 Johnson's Rep. (N. Y.), pp. 572-588-589.

In *Bassett* v. *Company*, the Supreme Court of New Hampshire say:

"Another principle which is held to govern the discretion of the court in these cases is that the application for the injunction

must be seasonably made, and therefore, if it appear that the owner of the property supposed to be affected by a nuisance has allowed it to exist for several years, with knowledge of its existence, *and without any objection*, and especially if he has acquiesced in the claim of another to use and enjoy the subject of complaint as of right, *and to expend money upon the strength of it*, with his knowledge and without objection, courts of equity will decline to grant an injunction, but leave him to his remedy at law. Nor would it be necessary that this acquiescence should be such as to be a defense to a suit at law, *although if a party stands by and sees another expend large sums of money in erecting what might in fact be a nuisance*, and such party is aware that the other supposes he has the right to do what he is doing, and yet such party makes no objection, although aware of his rights, he would be estopped both at law and equity. So is *Odlin* v. *Gove*, 41 N. H., 465."

The court then cites and quotes from the following cases, with approval:

(*The Rochdale Canal Co.* v. *King*, 2 Simons, N. S., 78; *Wood* v. *Sutcliffe*, 2 Simons, N. S., 163; *Birmingham Canal Co.* v. *Lloyd*, 18 Ves., 515; *Ripon et al.* v. *Hobart*, 3 Mylne & K., 169; *Barrett* v. *Blagrave*, 6 Ves., 104; Binney's Case, 2 Bland. Ch., 99 (Md.); *Jacox* v. *Clark*, Walk. Ch., 249 (Mich.), 2 U. S. Eq. Dig., 70, S. 137; *Gray* v. *Ohio & Penn. R. R.*, 1 Grant's Cases, 412; *Dunn* v. *Sprevier*, 7 Ves., 235.)

Bassett v. *Company*, 47 N. H. Rep., 426.

In the case of *Bliss* v. *Pritchard*, the Supreme Court of Missouri (the complainant in the case at bar) discussed the question of laches very fully, and laid down the principle substantially as follows:

"Laches is an equitable defense, and there is no artificial, fixed or determinate rule on this subject, but each case as it arises must be decided according to its own particular circumstances."

Bliss v. *Pritchard*, 67 Mo., 181, 190.

In the case of *Landrum* v. *Union Bank of Missouri*, the bank bought in a certain hotel property at a sale under a foreclosure of a trust deed, and then later sold the same property to other parties. The original owner of the property, some years later, deeded the property to the plaintiff in this suit, who then brought the suit asking that the sales to the bank, and by the bank to its vendee, should be set aside, on the ground that the consideration was so inadequate as to amount to fraud. It appeared that the bank laid out considerable money in keeping the property in good condition. The original owner knew all this, and yet made no protest nor any move to assert his rights until this case was brought. The Supreme Court of Missouri say:

"Viewed in any manner, there has been an utter lack of personal diligence in this case. The activity of equity powers can not be invoked where a party has negligently slept upon his rights and induced others to act upon the confident belief that he has abandoned them. Laches is an equitable defense, and there is no artificial, fixed or determinate rule on this subject; but each case as it arises must be decided according to its own particular circumstances. Courts of equity never give encouragement to the enforcement of stale or antiquated demands. In certain cases a comparatively brief period will be sufficient to bar a claim on the ground of laches, whilst in others courts will not stop short of the time of the statute of limitations. It all depends upon the character of the property, the knowledge and actions of the parties. In the present case the hotel property needed constant attention and care to prevent deterioration. The plaintiff by himself or agent was advised of all the facts, and knew everything that was going on. Why this delay? It is unaccountable. At all events we have no hesitation in arriving at the conclusion that there has been such a want of personal diligence as will prevent equitable relief being granted."

Landrum v. *Union Bank of Missouri*, 63 Mo. Rep., 48.

In the case of *Eston & McMahon* v. *New York & Long Branch R. R. Co.*, 24 N. J. Eq. Rep., 49, the bill was filed by

the attorney general at the relation of Easton and McMahon, and by the relators as complainants. The latter are shippers largely interested in the carrying trade on the Delaware and Raritan Canal. The object of the bill was to restrain the defendants from further proceeding in the erection of a bridge over the Raritan between South Amboy and Perth Amboy, and for the removal of so much of the structure as has already been built. The ground of complaint was, that the bridge was so constructed as to impede navigation, and was, therefore, a damage to the complainants and the public in general. The following extract from the opinion of the Court explains itself:

"It is worthy of remark, also, that the center pier of the draw had been built, and the whole structure so far completed as that a *few days' work* was all that was required to finish it, when the bill in this cause was filed.

"For many months the defendants have been permitted to proceed with the construction of the bridge. The amount of *their expenditures and liabilities incurred in the work is necessarily a very large sum.* It is claimed to be $200,000, besides the amount—over $50,000—of their purchases of land for the approaches and abutments of the bridge. *They have been engaged in this construction openly, in full view of all parties navigating the river, or being in Perth Amboy or South Amboy. The complainants can hardly have been unaware of the proposed plan of the bridge.* Up to the time of the commencement of this suit, the public have taken no action whatever in the premises. The relators have taken none in any court, until the filing of their bill in the Circuit Court of the United States for the District of New Jersey, in February of this year. *They certainly have known, from the time when the first piles were driven, where the defendants intended to locate the bridge; from that time, they have known what its general character was to be.* That was manifested by the mode of construction. They have made it part of this case, that notice was given to the defendants by the Delaware and Raritan Canal Company, on the 5th of December, 1871, of objections to the work. Those objections

were: That the bridge would cross the channel diagonally, and in such manner as to destroy the navigation. That it was located in an improper place, and that the defendants had no authority from the legislature to construct it. From this notice, it seems indisputable that the plan of the bridge was understood as early as December 2, 1871, the date of the notice. This notice was not given by the complainants, but if they are allowed the benefit of it, it will not avail them on this motion. It cannot be imputed to them for diligence. A mere objection or protest, or a mere threat to take legal, is not sufficient to exclude the consequence of laches or acquiescence in such a case as the present. A notice was indeed held to be sufficient in the case of *The Attorney General* v. *The Hudson River R. R. Co.*, 1 Stockt., 527, but in that case the notice was given before the work began, and the bill was filed in a very few days after the notice was served. If acquiescence cannot be imputed to the complainants, they certainly are chargeable with delay, which, though it may not amount to proof of acquiescence, may be sufficient to disentitle the complainants to the summary interference of the court, by interlocutory injunction; and this principle applies with equal force *where the act complained of is caused by a public company* in the execution and construction of their works. The extent of the expenditure is, *to a certain degree, the measure of the acquiescence.* Kerr on Injunctions, pp. 202-206. * * *

"The public, as represented by the attorney general, stand in no better position than the relators, and are bound by the like rules. Though a stronger case of delay is required to affect those who assert a public right than where a private right alone is in dispute, delay, even in such cases, is not without effect. *Attorney General* v. *Sheffield Gas Consumers Company*, 3 D. M. & G., 304.

"The work which it is sought to enjoin is a public enterprise of much importance to the people of this State, who, through their legislature, have authorized its construction. I find no evidence of bad faith on the part of the defendants, nor even

any imputation of it. This court is always reluctant to stay the progress of such enterprises, and will only do so in a case clearly calling for its intervention. *Allen* v. *Monmouth Freeholders*, 2 Beas., 68; *M. & E. R. R. Co.* v. *Pradden*, 5 C. E. Green, 537."

Eston & McMahon v. *N. Y. & L. B. R. R. Co.*, 24 N. J. Eq., 49.

XVIII.

II.

THE COURT OF EQUITY WILL REFUSE TO GRANT AN INJUNCTION WHEN IT APPEARS THAT GREATER INJURY AND INCONVENIENCE WILL BE CAUSED TO THE DEFENDANT BY GRANTING THE INJUNCTION THAN WILL BE CAUSED TO THE COMPLAINANT BY REFUSING IT.

In deciding the case at bar, the Court should, and undoubtedly will, take into consideration the question whether or not the granting of the injunction prayed for will not cause greater damage, injury and inconvenience to the defendants than a refusal to grant the injunction will cause to the complainant.

In cases of this kind, this question is always balanced, and an injunction will not be granted where it will be productive of greater injury than will result from a refusal of it. The following authorities lay this rule down very forcibly:

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8. *Balance of Convenience.*—On an application for an interlocutory injunction the court will always consider the balance of convenience; in other words, it will consider whether a greater injury would be done by granting an injunction than would result from a refusal, unless perhaps in cases where the wrong complained of is so wanton and unprovoked in its character as properly to deprive the wrong-doer of any consideration as to its injurious consequences. The courts will require a very strong case for the granting of an injunction *which will cause more injury than it will remedy, and it may be said, as a general rule, that an injunction will not be granted where it will be productive of greater injury than will result from a refusal of it.* This rule is especially applicable when the party applying for an injunction has by his own laches made it impossible to grant the injunction without inflicting serious injury on the party so to be enjoined.

In determining which way the balance of convenience lies, the resultant benefit and detriment to the parties litigant are not the only matters to be considered. *The court will also consider the injuries which may be inflicted on strangers* to the suit and to the public generally. The latter injuries, *superadded to those which will be inflicted on the defendant*, make a still stronger case for refusing an injunction, and may of themselves be a sufficient ground for refusing it."

(See, also, cited in support of the text in notes 6 and 9. These cases are too numerous to cite here, but are taken from the English Reports, the U. S. Reports, the Canadian Reports, and the reports of nearly all of the States holding the doctrine as laid down in the text.)

Amer. & Eng. Ency. of Law (2d Ed.), Vol. 16, pp. 363, 364.

"SEC. 23. *Writ Refused Where Cause of Justice Would Be Retarded or Defeated by Granting It.*—An injunction will not be granted where it would cause great injury to the defendant and might be a serious detriment to the public without corresponding benefit to the plaintiff. The question of relative convenience or inconvenience which may result to the parties by granting or withholding the writ is also often important. If, upon due consideration of such question, it is apparent that the act complained of is likely to result in irreparable injury to the complainant, and the balance of inconvenience preponderates in his favor, the injunction will be granted. On the other hand, if it appears that *the greater danger or inconvenience will result to defendant* rather than to plaintiff from granting it, or when the inconvenience seems equally divided as between the parties, the injunction will be refused, and the parties left as they are until a determination of legal rights can be had at law. Equal consideration will be given to the inconvenience, loss or injury to which the plaintiff would be subjected by a refusal to grant the injunction.

"SEC. 372. *Relative Loss and Injury to Parties.*—Though

a naked trespasser is not entitled to have the resulting loss of abstinence from the course of his wrong-doing considered by the court, yet where the damage is a consequence of the use of his own property, the comparative loss and inconvenience to the parties of granting or refusing injunction will be given considerable attention. Thus an injunction to restrain miners from working their mine so as to interfere with the ditch of another miner was denied where it appeared that the injunction would be ruinous to the defendants and of no benefit to the plaintiff, as the destruction of the ditch was inevitable, according to the plaintiff's testimony, from the work done by the defendant. And equity will refuse to enjoin where the complainant would derive no benefit from the exercise of his right."

Spelling on Extraordinary Relief, Vol. 1.

In the case of *Edwards* v. *Allouez Mining Co.*, the defendant, at a cost of some $60,000, erected a stamp mill on the banks of a certain creek, and as a result of its operations large quantities of sand were carried down by the waters of the stream and deposited on the bottom lands below. The plaintiff in the case purchased the bottom lands for speculative purposes, and then brought a suit to enjoin the defendant from allowing the sand to be discharged upon his land and from polluting the waters of the stream.

"An injunction is not a process to be lightly ordered in any case. Where the effect will be to present to the owners of a valuable mill the alternative either to purchase complainant's lands at his own price or to sacrifice their property, any court having the power to order it ought very carefully to scrutinize the case and make sure that equity requires it. In theory its purpose is to prevent irreparable mischief; it stays an evil the consequences of which could not adequately be compensated if it were suffered to go on. (Citing many cases.)

* * * * * *

"All the cases referred to show that the court looks beyond

the actual injury to contemplate the consequences, and however palpable may be the wrong, it will still balance the inconveniences of awarding or denying the writ, and adjudge as these may incline the judicial mind. *Grey* v. *Ohio, etc., R. R. Co.*, 1 Grant, 412; *Varney* v. *Pope*, 60 Me., 192; *Bosley* v. *M'Kim*, 7 Har. & J., 468."

Edwards v. *Allouez Mining Co.*, 38 Mich. Rep., 46.

Clifton v. *Dye*, 87 Ala., 468-70-71-72:

Counsel have pressed the proposition that mere convenience in the use of its property by the company does not entitle it to pour down upon the appellee's land, and into the stream on his land, the debris from the washers erected by it, and we think the contention is reasonable. But it is not every case of nuisance, or continuing trespass, which a court of equity will restrain by injunction. *In determining this question, the court should weigh the injury that may accrue to the one or the other party, and also to the public, by granting or refusing the injunction.* *Wood* v. *Sutcliffe*, 2 Sim., N. S., 162; *E. & W. R. R. Co.* v. *E. T., V. & G. R. R. Co.*, 75 Ala., 295; *C. & W. R. R. Co.* v. *Witherow*, 82 Ala., 190; 1 High on Injunc., Sec. 598; *Davis* v. *Sowell*, 77 Ala., 262; *Torrey* v. *Camden R. R. Co.*, 18 N. J. Eq., 293; *McBryde* v. *Sayre*, 86 Ala., 458.

But there is another ground which is fatal to complainant's right in a court of equity. The bill in this case was filed September 7, 1886, more than three years after the first washer was erected. Complainant saw the effect of it on the stream and made no objection thereto. The company then erected the second washer in 1884, and nearly two years elapsed before relief was sought. Clearly, it was the duty of complainant to give the company some intimation of his objection, and not to stand by with full knowledge and permit it to make large outlays on these washers and then seek the aid of a court of equity to arrest their operations. Reasonable diligence in the assertion of his rights was the measure of complainant's duty in this

case; and failing in this, he must now seek relief in a court of law for any damage he may have suffered. 1 High on Injunc., Sec. 797; *Wood* v. *Sutcliffe, supra.* Reversed and bill dismissed.

Clifton Iron Co. v. *Dye,* 87 Ala., 468-70-71-72.

The complainant was the owner of a dwelling house and cotton factory in the village of Phoenixville, Pennsylvania, and the respondents were owners of very extensive iron works in the same village. Their works were among the most extensive in the commonwealth, and consisted of several blast furnaces, some seventy puddling furnaces and rolling mills and other machinery. The plaintiff's dwelling was situated on a bluff about seventy feet above the nearest furnace floor, which brought its first story about on a level with the top of the puddling stacks, and when the wind was towards the plaintiff's house and from the furnace, the consequence was that it was at times enveloped in a coal smoke thrown out of the chimneys of the furnaces. This condition operated undoubtedly to materially injure the dwelling house as a dwelling and injury was also caused to the cotton factory, as the smoke blackened the stock and rendered the fabrics less saleable. The Court found from the facts that it was necessary for the defendants to use bituminous coal, and that for the work of puddling no smoke consuming device could be applied. The complainant asked the Court to restrain the defendants from using bituminous coal, which would practically put an end to their business and render their great plant useless. The Court says:

"An error seems somewhat prevalent, in portions, at least, of this Commonwealth, in regard to proceedings in equity to restrain the commission of nuisances. It seems to be supposed that, as at law, whenever a case is made out of wrongful acts on the one side and consequent injury on the other, a decree to restrain the act complained of must as certainly follow as a judgment would follow a verdict in a common law court. This

is a mistake. It is elementary law, that in equity a decree is never of right, as a judgment at law is, but of grace. *Hence the chancellor will consider whether he would not do a greater injury by enjoining than would result from refusing,* and leaving the party to his redress at the hands of a court and jury. *If in conscience the former should appear he will refuse to enjoin. Hiltio* v. *The Earl of Granville,* 1 Craig & Ph. Ch. R., 292; *Grey* v. *The Ohio and Penna. Railroad Co., supra.* We think this is a safe rule, and that the case we are considering is within it. With these views, and on full consideration of all the testimony in the case, we are of opinion the injunction was properly refused in the court below, and that the decree dismissing the plaintiff's bill with costs must be affirmed."

Richard's Appeal, 57 Pa. St., 114.

A complainant sought to enjoin a defendant from completing a brick wall that encroached a few inches upon a private alley, upon the ground that it was interfering with a right of way to which complainant was entitled.

"It may admit of some doubt whether a party is ever entitled as matter of right to a remedy by injunction to restrain the commission of a threatened injury. If the injury is likely to be irreparable the court will interfere; so it will for other reasons, but it will examine into all the circumstances of the case, and if it is apparent that the relief sought is disproportioned to the nature and extent of the injury sustained, or likely to be, the Court will not interfere, but will leave the parties to seek some other remedy. *Fox* v. *Holcomb,* 32 Mich., 495; *Briggs* v. *Withey,* 24 Mich., 136 *Norris* v. *Hill,* 1 Mich., 210; *White* v. *Forbes,* Walk. Ch., 114."

Hall v. *Rood,* 39-40 Mich., p. 46.

In *Campbell* v. *Seaman,* the New York Court of Appeals holds that while the case under consideration is not such a one as comes within the rule, that the law is as follows:

"It is true that if a party sleeps on his rights and allows a nuisance to go on without remonstrance, or without taking measures, either by suit at law or in equity, to protect his rights and *allows one to go on making large expenditures* about the business, which constitutes the nuisance, he will sometimes be regarded as guilty of such laches as to deprive him of equitable relief. (Citing *Radenhurst* v. *Coate*, 6 Grant's Ch. (Ont.), 140; *Heenan* v. *Dewar*, 18 *id.*, 438; *Bankart* v. *Houghton*, 27 Beav., 425.) * * *

Where the damage to one complaining of a nuisance is small or trifling and the damage to the one causing the nuisance will be large in case he be restrained, the courts will sometimes deny an injunction.

Campbell v. *Seaman*, 63 N. Y., pp. 568, 85, 86.

In the case of *Barnard et al.* v. *Gibson*, the parties to the suit claimed conflicting interests in a certain patented planing machine. The Court below granted an injunction against the defendants using the machines, and at the same time referred the case to a master to take evidence as to damages. As to the question of injunction the Court say:

"It is said that the decree in this case, by enjoining the defendants below from the use of their machines, destroys their value and places the defendants in a remediless condition. That in the course of a few months their right to run the machines will expire, and that no reparation can be obtained for the suspension of a right by the act of the Court. It is alleged, too, that many thousands of dollars have been invested in the machinery, which, by such a procedure, becomes useless.

"The hardship stated is an unanswerable objection to the operation of the injunction, until all the matters shall be finally adjusted."

Barnard et al. v. *Gibson*, 48 How. Rep., 650.

XIX.

III.

A COURT OF EQUITY WILL NOT GRANT AN INJUNCTION TO RESTRAIN A PARTY FROM COMMITTING A NUISANCE WHEN THE EVIDENCE SHOWS THAT THE PARTY COMPLAINING IS GUILTY OF CONTRIBUTING TO THE NUISANCE OF WHICH HE COMPLAINS. IF THE GRANTING OF AN INJUNCTION WILL NOT RELIEVE HIM FROM THE CONSEQUENCES OF HIS OWN ACTS THE INJUNCTION WILL NOT ISSUE. IF THE COMPLAINANT CONTRIBUTES TO THE CONDITIONS WHICH IT CLAIMS IN ITS BILL OF COMPLAINT WILL INJURE IT AS A STATE, IT CANNOT OBTAIN EQUITABLE RELIEF.

If the complainant contributes to the conditions which it claims in its bill will injure it as a State, it cannot obtain equitable relief.

It is the fundamental principle of equity that "He who seeks equity must do equity," and out of this grows the maxim that "He who comes into equity must come with clean hands."

In other words, courts of equity will not enjoin one from doing a lawful act upon the application of one who, while claiming said act will cause him great and irreparable injury, is himself contributing to the injurious condition complained of.

In such case the parties are in pari delicto.

We take it to be an undisputed fact that numerous cities, towns and villages in the State of Missouri, including the City of St. Louis, are emptying their sewage and drainage into the Mississippi River and its immediate tributaries. This offensive matter, cast into the waters by each of said cities, towns and villages, is carried down upon the next town below, which in its turn contributes its share to the pollution of the river, and so on from its source to its mouth.

The State of Missouri alleges in its bill that it will be injured as a *State* by reason of the pollution of the waters of the Mississippi by the defendants discharging into said waters the sewage from the Sanitary District. This alleged injury will

be suffered, if at all, by and through the municipalities of the complainant, which are its agents, and those very agents are contributing to the condition complained of.

The theory of the bill is that complainant is injured as a *State,* and the suit is not brought on behalf of any one city of the State.

The inhabitants of Missouri living above and below St. Louis have as much interest in this action as the people residing in St. Louis.

Any act of complainant committed by and through its municipal agencies contributing to the very nuisance complained of should bar its right to relief by the injunction of a court of equity, but in addition to this is the fact that it is discharging its own sewage and drainage, not only upon its own inhabitants, but also upon the inhabitants of the defendant, the State of Illinois, living upon the Illinois side of the Mississippi, opposite the Missouri shore.

The people of Illinois living upon the river shore are as much entitled to unpolluted water as are the people of Missouri.

The following cases, we think, sustain the theory that under such a state of facts the complainant is not entitled to relief in equity.

In *Harrington* v. *Bigelow*, the court held that where two parties had been concerned in the commission of a wrongful act, the Court would not lend its aid to either party.

11 Paige, 349 (N. Y.).

If the plaintiff himself has contributed to the pollution he cannot recover therefor against an upper proprietor.

Gould on Waters, page 433, Section 219.

The Topeka Water Supply Company commenced its action in the court below against the City of Potwin, its officers and employes, to perpetually enjoin the construction of a system of sewers for carrying off filth and refuse matter of the city into the Kansas River above the wells of the company, and also to prevent the officers, agents and employes of that city from using the river for any like purpose.

The Water Company sank wells upon an island in the Kansas River, into which the water percolated from the river, and in passing through the earth and gravel became filtered. From these wells the company drew its water for the supply of its customers. The company also laid a pipe from the river directly connecting with its wells, so that when the water was very low, or when there was a special drain upon the supply, as in case of fire, the company could fill up its wells with the unfiltered water from the river.

Under the ordinance by which the Water Company was given the right to furnish water to the City of Topeka, it was required to furnish said city "a full and sufficient supply of good, clear, healthful and wholesome water, well suited for domestic and manufacturing purposes."

It appeared clearly from the evidence that the company did not furnish water of the character described, but that it was frequently little better than the water flowing in the river, which was polluted by the drainage from a large tract of country, and from a portion of the City of Topeka and the drainage of an insane asylum, whose buildings were constantly occupied by several hundred inmates.

The court say:

"*But above all, and worse than all, according to the findings of the court below, the Water Company is itself a wrong-doer,* violating its contract with the city, violating the city ordinance, and violating the duty and obligation by furnishing water to the City of Topeka and to its inhabitants which is unfit for use."

Now, the question arising upon these facts is not whether a party, in the rightful and legal exercises of a legitimate business, has the right to restrain some wrong-doer from committing acts which will seriously and injuriously interfere with and affect such party's lawful and rightful business, but *it is whether one wrong-doer may obtain an injunction to restrain another wrong-doer from committing an act which could not,* possibly, under any circumstances, do the plaintiff any harm, if the plaintiff himself, or itself, do right and obey the law, and

where the absolute refraining by the defendant and all others from the commission of the act or acts complained of, and from all other wrongful acts, would not, and could not, possibly, under any circumstances, enable the plaintiff to do right and to obey the law, if the plaintiff should still continue to carry on the business sought to be protected by the injunction. * * *

"The party seeking relief cannot say to the person whom he or it wishes to have enjoined: 'It is true I will not be injured by your wrongful act or acts provided I do right myself, but I do not intend to do right. I expect to violate duty, obligation of contracts, the city ordinances, and to infringe upon the dearest and most valued rights of others, and by so doing I expect, if you do not interfere, to reap other great reprehensive advantage; but if you do interfere, it will prevent me from reaping this much coveted and contemplated advantage, and, therefore, as you are an accepted and intended wrong-doer, as well as myself, you should be restrained from the commission of your contemplated wrongs, in order that I may commit my own.'

"In the findings of the trial court, the Topeka Water Supply Company may, if it chooses, obtain reasonably good water by going further up the river to a place above Potwin Place, above the insane asylum, and getting its supply of water there; but according to such findings it cannot obtain good water from the place from which it now obtains its supply. If it should go above Potwin Place and there obtain its water, then no act or acts on the part of Potwin Place could possibly do it any harm, and according to the findings of the court below it cannot obtain good water below Potwin Place, and at or above the place from which it now obtains its water. It can there obtain only such water as is unfit for use, and obtaining the same there, and furnishing it to the City of Topeka, and to the inhabitants thereof, it not only does wrong, but it also violates its contract, and violates the city ordinance. Will a court of equity encourage any such thing?

"Any such would be a violation of some of the best estab-

lished maxims of equity. This is an equitable action and it is a general rule of equity that he who seeks equity must do equity.

"And it is also a general rule of equity that he who goes into a court of equity must do so with clean hands. In other words, a party can obtain no order, judgment or decree from a court of equity for the purpose that he may, with greater profit, or advantage, violate the rules of equity.

"The granting of an injunction in this case could be of no possible benefit or value to the plaintiff, provided it should do right itself.

"If the findings of the court below are correct, then not all the injunctions which all the courts of Kansas, or elsewhere, could grant, would be sufficient to enable the plaintiff to furnish from the place where it now obtains its supply 'good, clear, healthful and wholesome water, well suited for domestic and manufacturing purposes.'

"And courts of equity are not swift to grant futile, worthless or fruitless orders. Although both parties in this case are wrong-doers, yet this is not merely a question of balancing wrongs as between such wrong-doers.

"*The party seeking the relief must himself, or itself, do right, or it is not entitled to the relief sought.* There are differences, however, between the wrongs of these two wrong-doers, some of which we might mention.

"The plaintiff's wrongs are not only contemplated, but they are also present, as well as past, and consummated; while the defendant's wrongs are only in prospect, merely contemplated, or expected. * * *

"It would result in some loss to either party to refrain from the commission of its contemplated and intended wrongful acts.

"The plaintiff, at some loss, would have to go further up the river to procure good water, while the defendant, the City of Potwin Place, at a loss of about seventy-five thousand dollars, to the findings of the court below, would have to go further down the river to discharge its sewage.

"But if it should go further down the river to discharge its sewage, would not some still lower riparian proprietor, the owner of a town lot, for instance, worth a few dollars, commence an action of restraining such city from discharging its sewage there?

"And such lower riparian proprietor, if he were an individual person, would probably have real and substantial riparian rights.

"If the plaintiff could obtain good water from the place where it is now obtaining it, except from the contemplated wrongful acts of the defendant, then we would think that the plaintiff would have a right to an injunction.

"Even if the defendant and all others should do right and obey the law, still the plaintiff would not be able, from the place where it now procures its water, to obtain that kind of water which it has agreed to furnish to the City of Topeka, and to the inhabitants thereof, and which kind only it has any right to so furnish. * * *

"*A controlling fact in this case, aside from other facts, is that the plaintiff is a wrong-doer*, and that it cannot be anything else than a wrong-doer and be injured by the contemplated acts of the defendant.

"The defendants have also cited a considerable number of cases, among which is the case of *Wood* v. *Sutcliffe*, 8 Eng. L. Eq., 217 (2 Simon's Chancery, N. S., 163), which seems to have the fullest application of any case cited on either side.

"We do not know of any case having entire application to this case, hence in the consideration of this case, upon this motion for a rehearing, we have considered the same almost entirely upon the general rules, principles and maxims of law and equity, and especially upon the following general maxims in equity, to wit: 'He who comes into equity must come with clean hands;' He that hath committed inequity shall not have equity, and he who seeks equity must do equity."

Water Supply Company v. *City of Potwin*, 43 Kansas, pp. 408-419, inclusive.

Ferguson v. *The Fimendich Manuf. Co.:*

Plaintiff is the owner of the four hundred and twelve acres of land through which Linn Creek flows from the southwest in a northeasterly direction into the Iowa River. He resided upon his land, and uses it in part as a stock and dairy farm. The defendant operates a glucose factory, situated on the creek aforesaid, about half a mile northwest of the farm of plaintiff:

"In November, 1885, plaintiff leased, for the purpose of putting in a slaughter house thereon, a small tract of ground near his dwelling, and on Linn Creek, 'with the privilege of the creek.' There was evidence to the effect that a slaughter house was constructed under the lease and operated during 1887; that much animal matter was thrown therefrom into the creek, and permitted to corrupt its water; that other animal matter was thrown about the slaughter house and there permitted to decay; that the slaughter house was a nuisance, for which the *plaintiff* was in part responsible, and to that source and other causes due to him, much of the evil of which he complains is attributable. The responsibility of plaintiff for the condition of the stream and the odors in controversy was put in issue by the answer. Appellant sought to establish that responsibility during the trial, and asked an instruction in regard to it, which was refused. The Court charged the jury that, 'If it appears that the offensive exhalations were caused by the act or omission of *plaintiff* himself, or by others, acting without the co-operation, connivance or assistance of the defendant, that he cannot recover anything on account of such alleged annoyance or disturbance in the comfortable use and enjoyment of his premises;' but it failed to charge them as to the effect of contribution by plaintiff to the results of which he complains. It is insisted by appellee that he is entitled to recover, if a wrong has been proven, notwithstanding the fact that he may have contributed to it. *We do not think his position is well taken. If he contributed to the wrong, he and defendant were joint wrong-doers. In law the act of each was the act of both.*

"It was said in *Turner* v. *Hitchcock*, 20 Iowa, 318, that there is no contribution among tort-feasors, who have knowingly committed a wrong, and that the demand is not severable or apportionable between them. See, also, 1 Hill, Torts, 176, note 3; *Metz* v. *Soule*, 40 Iowa, 238; *Cassady* v. *Cavenork*, 37 Iowa, 300. It is true the answer charges that the demand of which plaintiff complains was the result of his own acts in maintaining a slaughter house, but *it also sets out various alleged acts of plaintiff which were contributory in their nature*, and the efforts of defendant during the trial were largely directed to showing contribution on the part of the plaintiff. The instruction in regard to contribution asked by defendant was objectionable in some respects, but *it directed attention to that issue, and an instruction in regard to it should have been given. Acts of plaintiff sufficient to defeat its recovery would be such as contributed to cause those things of which he complains.*"

Ferguson v. *Firmenich Manuf. Co.*, 77 Iowa, 576-77-79-80.

In the case of *Cassady* v. *Cavenor*, the complainant brought a suit in equity to abate a nuisance he complained to arise from offensive odors destructive to the health and the comfort of himself and family, which was caused, as he complains, by the defendant's stable, hog pen, sewer and vault.

The plaintiff's and defendant's premises were adjacent, and the plaintiff's house set back near the rear of line of the lot. The plaintiff himself was proprietor of two hog pens, a stable, a hen house and a vault, not far from his dwelling house.

It appeared from the evidence that the defendant took reasonable care to keep his premises clean and inoffensive, and it also appeared that the plaintiff was anything but a model of cleanliness and neatness.

The Court, after reviewing the facts quite fully, say:

"If one coming into a court of equity for relief must do so with clean hands, it is not unreasonable that he should not be allowed to abate his neighbor's premises because of their

uncleanliness, when it appears that his own are equally filthy." Citing *Carter* v. *Winslow*, 38 Vermont, 691.

The court affirmed the judgment of the District Court, dismissing the plaintiff's petition and the defendant's counterclaim.

Cassady v. *Cavenor*, 37 Iowa, 300-305.

In the case of *Richards* v. *The City of Waupun*, the city built a sewer in a street near plaintiff's premises, and several of his neighbors constructed private sewers connecting with it. The plaintiff, in refilling the excavation, left the surface considerably lower than the surface of the fronts of his neighbors' lots.

The result was that when the weather became wet the surface water accumulated in this low part of the plaintiff's lot, causing a mudhole, for the continued allowance of which the plaintiff brought suit against the city.

It appeared that one of the city aldermen had acquiesced in the work done by plaintiff and his neighbors, but no other wrongful act was alleged as having been done by the city, and it did not appear that the mudhole had become a public nuisance.

The Court say:

"Can the plaintiff recover damages from the city for a mudhole upon the front end of his own lot, created by himself, or at most by the joint act of himself and his two neighbors? It may be difficult to find any adjudicated case where a person has sought to recover damages of the city in which he lived merely because he had himself, and of his neighbors' own volition, or in conjunction with others, created a nuisance upon his own lot. we have no disposition to search for an authority precisely in point upon a question so clearly resolvable upon the well established maxims of law. * * *

"'That to which a man consents, or causes by his own action, cannot be considered injury for which he can recover damages.'

"Clearly the plaintiff has no cause for action against the city. *Volenti non fit injuria.* Non-suit should have been granted."

Richards v. *The City of Waupun*, 59 Wis., pp. 45-47.

D. Y. Mowday v. *S. M. Moore:*

The plaintiff erected upon his town lot a building with a cellar under it, knowing that the soil was spongy, and that upon the adjoining lot of defendant was a race-way, the water from which passed to plaintiff's cellar when he was building, but, notwithstanding, he proceeded without using precautions which would have afforded protection.

Before the erection of plaintiff's building, the defendant had erected buildings upon his lot without cellars and with cross-walls, from the wall of the race-way to the plaintiff's line, constructed in regular and proper manner. The plaintiff could not sustain a bill for a decree requiring the defendant so to reconstruct his buildings that the water would not pass to the plaintiff's premises.

Mowday v. *Moore*, 133 Penn. St., 598.

Defendant's ancestor conveyed to the plaintiff's grantor certain real estate, on which stood a carding machine and clothing works and shops; and also granted the privilege of drawing from their dam a sufficient quantity of water "for the use of said works." From the time of the grant, and for more than forty years, an open space in front of the mill, which belonged to the defendant, had been used for piling and sawing wood for the use of the mill. Plaintiff placed thereon a buzz-saw, propelled by the water from the defendant's dam. Defendant thereupon shut off the water, and plaintiff obtained judgment, enjoining defendants from depriving him of the water to which he was entitled under his deed.

"*It is a rule of equity that he who seeks equity must do*

equity. The plaintiff was in fault in using the buzz-saw on the defendants' premises. It is said that this was an independent transaction, for which the defendants might have an action; and this was the view of the court below. The rule referred to will be applied when the adverse equity grows out of the very controversy before the court, or of such circumstances as the record shows to be a part of its history, or is so connected in the cause in litigation as to be presented in the pleadings and proofs, with full opportunity afforded to the party thus recriminated to explain or refute the charges. (*Tripp* v. *Cook*, 26 Wend., 143; *McDonald* v. *Neilson*, 2 Cow., 190; *Casler* v. *Shipman*, 35 N. Y., 533."

Comstock v. *Johnson et al.*, 46 N. Y. Rep., 615.

A bill for injunction was filed to stay all proceedings upon a judgment recovered against the company and others in a suit at law. The judgment was upon a note given and payment for a number of slaves. The contract for the slaves and the notes were executed at Vicksburg, Mississippi, and such a contract was against the law of Mississippi. The complaint relied upon the illegality of the transaction as a ground for enjoining the collection of the judgment. Mr. Justice Daniel, in delivering the opinion of the court, said as follows:

"In reviewing the grounds relied on by the complainant as the foundation of his claim for relief, the second and third, being coincident with the order and progress of the transactions between the parties as stated in the bill, and evincing especially the circumstances and the attitude under which this approach to a court of equity has been made, will be first considered, and this examination will be premised by stating the following principles of equity jurisprudence which may be affirmed to be without exception: that whosoever would seek admission into a court of equity must come with clean hands; that such a court will never interfere in opposition to conscience or good faith; and, again, and in intimate connection with the principles just

stated, that it will never be called into activity to remedy the consequences of laches or neglect, or the want of reasonable diligence. Whenever, therefore, a competent remedy or defense shall have existed at law, the party who may have neglected to use it will never be permitted here to supply the omission to the encouragement of useless and expensive litigation, and perhaps to the subversion of justice. The effect of these principles upon the statements of the complainant is obvious upon the slightest inspection. The complainant alleges that the obligation to which he had voluntarily become a party was intentionally made in fraud of the law, and for this reason he prays to be relieved from its fulfillment. This prayer, too, is preferred to a court of conscience, to a court which touches nothing that is impure. The condign and appropriate answer to such a prayer from such a tribunal is said, *that, however unworthy may have been the conduct of your opponent, you are confessedly in pari delicto;* you cannot be admitted here to plead your own demerits; precisely, therefore, in the position in which you have placed yourself, in that position we must leave you."

Creath's Admr. v. *Sims*, 46 Howard's Rep., 192.

The case of *Sample* v. *Barnes* was a suit to enjoin the collection of certain judgments. The Court says:

"This rule, as applicable to the position of this party, a rule believed to be without exception, has been distinctly announced by this court in a case very similar in most of its features to the one now before us; for that, like the present, was a case in which the contract was impeached for precisely the same reason for which the interposition of equity was here invoked; and in that, too, as in this instance, after the omission to set up a defense at law. We allude to the case of *Creath's Administrator* v. *Sims*, in the 5th Howard, where this court, on page 204, have thus announced the rule by which courts of equity are governed. 'Whosoever,' say they, 'would seek admission into a court of equity must come with clean hands, and

such a court will never interfere in opposition to conscience or good faith. The effect of these principles upon the statements of the complainant is obvious upon the slightest consideration. The complainant alleges that the obligation to which he had voluntarily become a party was intentionally made in fraud of the law, and for this reason he prays to be relieved from its fulfillment. This prayer, too, is addressed to a court of conscience, to a court which touches nothing which is impure. The condign and appropriate answer from such a tribunal to such a prayer is this, that, however unworthy may have been the conduct of your opponent, you are confessedly *in pari delicto;* you cannot be permitted here to plead your own demerits; precisely, therefore, in the position in which you have placed yourself, in that position we must leave you.'"

Sample et al. v. *Barnes,* 14 Howard's Rep., U. S., 70.

In *Palmer* v. *Harris,* the case having been heard on the bill and answer, the bill was dismissed with costs. The court quotes the maxim, "He who comes into equity must come with clean hands," and also "He that hath committed inequity shall not have equity."

"Sharswood, J.—The plaintiff, according to the statements of his bill, is the manufacturer of a cigar known as the 'Golden Crown,' and he has devised a trade-mark, which he uses in its sale. He charges that the defendant, who is a printer by trade, has counterfeited this mark, and sells copies of it to persons engaged in the manufacture and sale of cigars, by whom they are used, to his damage. The answer of the defendant admits these allegations, but sets up as a ground for the non-interference of the court that the articles thus sold by the plaintiff were manufactured in the City of New York, and that the trade-mark in question contains upon it the declaration that they are the product of a 'factory of cigars from the best plantations de la Vuelta Abajo, Calle del Agua, Habana.'"

As this declaration was not true, the plaintiff was denied relief.

The ground taken by the court was, substantially, that the complainant having himself acted wrongfully in the very matter complained of in his bill of complaint, could not invoke the powers of a court of chancery to aid him. The principle governing the case is contained in the maxim quoted.

Palmer v. *Harris,* 60 Pa. St. Rep., 156.

In the case of *Parlett* v. *Guggenheimer,* the facts were very similar to the foregoing case. It involved the right to use a trade-mark, and the court held that one who had himself acted wrongfully could not invoke the powers of a court of equity in his aid. The Court, in its opinion, says:

"In this last case the judge in his opinion says, 'Those who come into a court of equity seeking equity must come with pure hands and a pure conscience. If the sales made by the plaintiff are effected, or sought to be, by misrepresentation and falsehood, he cannot be listened to when he complains that by the fraudulent rivalry of others his own fraudulent profits are diminished. An exclusive privilege for deceiving the public is assuredly not one that a court of equity can be required to sanction. To do so would be to forfeit its name and character.'"

Parlett v. *Guggenheimer,* 798 Cent. Rep., 796.

"Sec. 371. *Complainant Required to Do Equity.*—There applies to this class of cases another rule of general application; and that is, that he who seeks extraordinary relief by injunction against another, though it be on account of a wrongful act amounting to a tort, must be willing and ready to do what is just and equitable in the premises. This principle or maxim was applied in a recent case. Plaintiff, an electric company, entered into a contract with defendant, an electrical subway company, by which plaintiff was to use defendant's subways, paying therefore a certain sum as rent. After several years'

use of the subway without payment of rent, the subway company demanded the rent, and threatened to cut out and remove plaintiff's cables in default of its payment. It was held, in an action for an injunction to restrain such proceedings, waiving the question whether the court had or had not jurisdiction to grant an injunction under special laws relating to the subject-matter of the controversy, that plaintiff could not ask the intervention of a court of equity until it had paid whatever rent was due before the commencement of its proceedings."

Spelling on Extraordinary Relief, Vol. 1.

In the case of *City of Jacksonville* v. *Doane*, the appellee brought suit against the city for damages said to have been caused by odors from a sewer under the control of the city, which discharged into a creek in the neighborhood of plaintiff's house. It appeared from the evidence that the creek became obstructed near the plaintiff's premises, causing the filth to accumulate there, and to increase the annoyance to Doane. In regard to this the Court say:

"It is true that plaintiff was required to exercise ordinary care to avoid the damages of which he complains, *and if he materially contributed to the injury he could not recover.* If the plaintiff suffered obstructions to accumulate in the creek on his own land, and these obstructions were the cause of the damages complained of by the plaintiff, he ought not to recover."

City of Jacksonville v. *Doane*, 145 Ill., 23, 26.

MUNICIPAL CORPORATIONS AGENCIES OF THE STATE.

The cities, towns and villages in the State of Missouri, situated upon the shore of the Missouri River, which are contributing to the nuisance complained of in this suit, are all agencies of the State; their acts in so contributing will be imputed to the State, and it should not be given relief from a condition

to which its agencies are so materially contributing. The following cases illustrate the relation between a State and the municipal corporations existing within it.

"The several towns and cities are agencies of government largely under the control of the legislature. The powers and duties of all the towns and cities, except so far as they are specifically provided for in the Constitution, are created and defined by the legislature; and we have no doubt that it has the right in its discretion to change the powers and duties created by itself, and to vest such powers and duties in officers appointed by the Governor, if in its judgment the public good requires this, instead of leaving such officers to be elected by the people or appointed by the municipal authorities."

Commonwealth of Massachusetts v. *Plaisted*, 2 L. R. A., 142.

(See note to this case entitled "Municipal Corporation as Agencies of Government," which discusses the question very fully and cites cases from very many of the States supporting the proposition.)

"A municipal corporation like the City of Baltimore, is a representative not only of the State, but is a portion of its governmental power. It is one of its creatures, made for a specific purpose, to exercise within a limited sphere the powers of the State. The State may withdraw these local powers of government at pleasure, and may, through its legislature or other appointed channels, govern the local territory as it governs the State at large. It may enlarge or contract its powers or destroy its existence."

United States v. *Railroad Company*, 84 Wallace, 322.

"Municipal corporations are created by the legislature, and they derive all their powers from the source of their creation; and those powers are at all times subject to the control of the legislature."

Rogers v. *Burlington*, 70 Wallace Rep., 654.

"Municipal corporations are mere instrumentalities of the State for the more convenient administration of local government. Their powers are such as the legislature may confer, and these may be enlarged, abridged, or entirely withdrawn at its pleasure."

Meriwether v. *Garrett*, 102 U. S. Rep., 472.

"But between the State and municipal corporations, such as cities, counties and towns, the relation is different from that between the State and the individual. Municipal corporations are mere instrumentalities of the State, for the convenient administration of government; and their powers may be qualified, enlarged or withdrawn, at the pleasure of the legislature."

Commissioners, etc. v. *Lucas, Treasurer*, 93 U. S. Rep., 108.

"Incorporated cities and villages, among others, were selected to act as such governmental agencies, within their respective territorial jurisdictions, and were clothed with such power as the law-making department deemed proper to entrust to them. Though a city is regarded as a corporation created for its own benefit, and as having been invested with corporate life and power by its own desire, and at its own invitation, still in the exercise of many of the powers conferred upon it by the General Assembly, the city is but the representative of the general government of the State."

City of Chicago v. *Chicago Ball Club*, 196 Ill., 59, 60.

"Again, municipalities, such as counties, cities, villages, towns, school districts and, in the language of the act, all other municipal corporations, and the corporations of all charitable, educational, penal or reformatory institutions under the patronage and control of the State, and all public officers, when suing

or defending in their official capacity, for the benefit of the public, are the instruments of the State to carry out its powers for the public welfare, and in exercising their powers, and enforcing public rights, they act as agents, and may have extended to them the same exemptions in suits as belonged to the State. Municipal bodies act for the State, and to the extent authorized exercise the powers of government, and when so exercising such powers, they may, when so authoried, do so without conforming to all the requirements imposed by the practice on natural or artificial persons created for the purposes of business or gain."

Holmes v. *City of Mattoon*, 111 Ill., p. 30.

"A municipal corporation is an agent of the State; the State itself is a sovereignty, and has all the benefits, rights and immuntities of a sovereignty, and it has been held that if a State be not named in the act, it is not bound, following the old common law principle, that a sovereign is not bound by an act of Parliament, unless expressly named therein."

Strauss v. *Conn.*, 1 Duv., 149; *State* v. *Crutcher*, 2 Swan, 504; *Piper* v. *Richardson*, 9 Metc., 155; *Soady* v. *Richardson*, 3 Ad. & El., 240.

XX.

IV.

THAT THE EVIDENCE OF E. E. LOCKRIDGE, ONE OF THE COMPLAINANT'S WITNESSES, WHO TESTIFIED TO THE CONTENTS OF THE PUBLIC RECORDS OF THE MORTUARY OFFICE OF THE CITY OF ST. LOUIS FROM PERSONAL EXAMINATIONS, IS OBJECTIONABLE FOR THE REASON THAT THE RECORD ITSELF OR A DULY CERTIFIED COPY OF IT IS THE BEST EVIDENCE, AND NO LEGAL FOUNDATION WAS LAID FOR THE INTRODUCTION OF SECONDARY EVIDENCE TO PROVE ITS CONTENTS. THE CONTENTS OF A PUBLIC RECORD CANNOT BE PROVED BY PAROLE EVIDENCE AND THEREFORE HIS TESTIMONY SHOULD BE EXCLUDED BY THE COURT.

That the testimony given by Mr. Lochridge is so plainly objectionable, defendants do not desire to consume much of the time of the court in discussing it. This witness went into the mortuary office in the City of St. Louis, looked through certain books purporting to be the mortuary record, made pencil memoranda from the books, and from these pencil memoranda made up a number of tables and charts, which were introduced in evidence in this case over the objection of defendants, for the reasons stated in the objection, that the public records of the mortuary office, if admissible at all, are the best evidence, and that a public record cannot be proven by parol evidence. Mr. Lochridge in his testimony states: "All the work was done in the office of Mr. Smyth, the clerk of the mortuary office. He looked over all that I had copied, and I asked him to check certain places, which he did, finding the number the same. I did every bit of the work myself and was assisted only in the way mentioned." (7952.) As evidence that these records could have been produced, defendants call the court's attention to the fact that after the objection of Mr. Todd to Mr. Lochridge's testimony (7953), Mr. Jeffries requested the Commissioner to issue a subpoena *duces tecum* for Mr. Smyth, mortuary clerk, for the mortuary record containing the deaths from typhoid,

typho-malaria, intermittent, remittent, congestive, simple continued, bilious and malarial fevers, for the years 1896 to 1903, inclusive. (7954.) And no return, so far as the record in this case discloses, was ever made to that subpoena; and the defendants contend that they had a right to demand that evidence in order to be competent must be the best evidence.

TO PROVE A FACT OF RECORD WITHOUT THE PRODUCTION OF THE RECORD ITSELF, A DULY AUTHENTICATED COPY OF THE RECORD, OR SO MUCH THEREOF AS RELATES TO THE FACT IN QUESTION IS REQUIRED. A CERTIFICATE BY A PUBLIC OFFICER HAVING THE LAWFUL CUSTODY OF PUBLIC RECORDS AS TO ANY FACT APPEARING ON THE RECORDS OF HIS OFFICE OR AS TO ANY CONCLUSION HE MAY DRAW FROM AN INSPECTION OF THE RECORDS IS NOT COMPETENT EVIDENCE.

Mandel v. *Swan Land, etc. Co.*, 154 Ill., 177.
People v. *Lee*, 112 Ill., 113.
Scott v. *People*, 89 Ill., 195.
Chicago v. *English*, 80 Ill. App., 163.
Compare Chambers v. *People*, 5 Ill., 351.
Fangan v. *U. S.*, 24 Ct. Cl., 217.
Dunn v. *Games*, 8 Fed. Cas. No. 4, 176, 1 McLean, 321 (affirmed in 14 Pet., 322, 10 L. Ed., 476.)
U. S. v. *Edwards*, 25 Fed. Cas. No. 15,026, 1 McLean, 467.
U. S. v. *Patterson*, 27 Fed. Cas. No. 16,000, Gilp., 44.
Compare Hoffman v. *Pack*, 144 Mich., 1, 71 N. W., 1095.
Enfield v. *Ellington*, 67 Conn., 459, 34 Atl., 818.
New Milford v. *Sherman*, 21 Conn., 101.
Cornelison v. *Browing*, 9 B. Mon., 50.
Fletcher v. *Cavalier*, 4 La., 272.
Jay v. *East Livermore*, 56 Me., 107.
Wayland v. *Ware*, 109 Mass., 248.
Robbins v. *Townsend*, 20 Pick., 345.
Davis v. *Gray*, 17 Ohio St., 330.

PAROLE EVIDENCE OF THE CONTENTS OF A WRITTEN INSTRUMENT IS INADMISSIBLE, WHERE THE INSTRUMENT ITSELF CAN BE PRODUCED.

Bouldin v. *Massie's Heirs*, 20 U. S. (7 Wheat) 122, 5 L. Ed., 414.
Sebree v. *Dorr*, 22 U. S. (9 Wheat.) 558, 6 L. Ed., 160.
United States v. *Lynn*, Fed. Cas. No. 15,649 (2 Cranch, C. C. 309.)
Rinaldi v. *Rivers*, 1 Stew., 174.
Cloud v. *Patterson*, Id., 394.
Wiswall v. *Knevals*, 18 Ala., 65.
Richards v. *Stewart*, 2 Day, 328.
Newson v. *Jackson*, 26 Ga., 241, 71 Am. Dec., 206.
Meek v. *Spencer*, 8 Ind., 118.
Marks v. *Winter*, 19 La. Ann., 445.
Kimball v. *Morrill*, 4 Me. (4 Greenl.) 368.
Mulliken v. *Boyce*, 1 Gill., 60.
Dunnock v. *Dunnock*, 3 Md. Ch., 140.
Boynton v. *Rees*, 25 Mass. (8 Pick.) 329, 19 Am. Dec., 326.
Northrup v. *Jackson*, 13 Wend., 85.

XXI.

V.

THAT AN INJUNCTION TO RESTRAIN A NUISANCE WILL ISSUE ONLY IN A CASE WHERE THE FACT OF NUISANCE IS MADE OUT UPON DETERMINATE AND SATISFACTORY EVIDENCE. THAT IF THE EVIDENCE BE CONFLICTING AND THE INJURY BE DOUBTFUL, THAT CONFLICT AND DOUBT WILL BE A GROUND FOR WITHHOLDING THE INJUNCTION, AND THAT WHERE INTERPOSITION BY INJUNCTION IS SOUGHT TO RESTRAIN, THAT WHICH IS APPREHENDED WILL CREATE A NUISANCE OF WHICH ITS COMPLAINANT MAY COMPLAIN, THE PROOF MUST SHOW SUCH A STATE OF FACTS AS WILL MANIFEST THE DANGER TO BE REAL AND IMMEDIATE.

The above proposition is taken from the opinion of this court, delivered at the time that the demurrer to complainants' bill was overruled.

CONCLUSION

A careful consideration of all the testimony given in this case fails to establish as a fact that the opening of the Drainage Canal is a nuisance, causing complainant great and irreparable injury. The contention made by complainant has not been made out upon determinate and satisfactory evidence. Based upon the testimony given in this case on the part of complainant, the evidence is conflicting and the injury doubtful, and consequently complainant is not entitled to the relief prayed for in its bill of complaint. The evidence in this case establishes affirmatively that the State of Missouri, as a State, is not injured or damaged by virtue of the opening of the Chicago Drainage Canal, but on the contrary, if there has been an injury established in the evidence in this case as suffered by the inhabitants of the State of Missouri from the use of the waters of the Mississippi River, that injury has been caused by the inhabitants of the cities, towns and villages within the jurisdiction of complainant who have emptied their sewage into the Missouri and Mississippi Rivers at points above the places where the alleged injury is suposed to have existed. The evidence upon which damage is predicated is speculative and theoretical, and insufficient to show that the opening of the Chicago Drainage Canal is responsible for the injury complained of. The defendants in this case contend that the evidence shows that a typhoid germ will not live to make the journey from Chicago to St. Louis; that the opening of the Chicago Drainage Canal with the sewage of Chicago diluted with the pure water of Lake Michigan has had a good sanitary effect upon the waters of the Illinois River, and that the Illinois River, since January 17, 1900, has been in a better sanitary condition than it was before; that the Illinois River, prior to and since 1900, has been less polluted and infected than is the Mississippi or Missouri Rivers, and consequently the waters of the Illinois, mixing with the waters of the Mississippi and Missouri

Rivers, have tended to improve instead of causing an injury to those waters; that the typhoid condition existing in the City of St. Louis prior to 1900, when compared with conditions existing since 1900, do not show an increase such as could be charged to an infected water supply, and the evidence in this case fails to establish by satisfactory evidence the real typhoid conditions that exist in the City of St. Louis, for the reason, as the evidence shows, the physicians of St. Louis have made mistakes in reporting typhoid deaths to the Board of Health by reporting them under some other and different headings. Taking all the facts in this case, in connection with the typhoid conditions in St. Louis, defendants contend that the evidence fails to show an increase of typhoid fever in the City of St. Louis, and that the evidence utterly fails to connect the typhoid conditions existing in St. Louis with the typhoid conditions existing in the City of Chicago. When all these facts are taken into consideration, the conclusion is irresistible that the opening of the Chicago Drainage Canal has not injuriously affected the health of the inhabitants of the State of Missouri or of the citizens of the City of St. Louis, nor has it injured the water of the Mississippi River as the same passes by the State of Missouri for agricultural and mechanical purposes, and consequently, there being no injury established on the part of complainant by determinate and satisfactory evidence in this case, the defendants submit that complainant is not entitled to an injunction, and asks to have its bill of complaint dismissed.

Respectfully submitted.

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W. H. STEAD,
Attorney General of Illinois.

H. J. HAMLIN and
JOHN G. DRENNAN,
of Counsel.

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(B) THE TYPHOID GERMS FROM CHICAGO WILL NOT MAKE THE JOURNEY TO THE MISSISSIPPI RIVER AND BECOME A DANGER AND A MENACE TO THE INHABITANTS OF THE STATE OF MISSOURI TAKING THEIR WATER SUPPLY FROM THE WATERS OF THE MISSISSIPPI RIVER.

(C) THE OPENING OF THE DRAINAGE CANAL IS NOT A DANGER AND A MENACE, PRESENT OR IMPENDING, TO THE INHABITANTS OF THE STATE OF MISSOURI TAKING THEIR WATER SUPPLY FROM THE MISSISSIPPI RIVER.

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